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WALNUT CULTURE IN CALIFORNIA

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Revised by L. D. BATCHELOR and O. LEE BRAUCHER

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WALNUT CULTURE IN CALIFORNIA

L. D. BATCHELOR[1]

Revised by L. D. Batchelor and O. Lee Braucher[2]

GENERAL REVIEW OF THE WALNUT INDUSTRY

The Persian walnut (*Juglans regia*), more commonly known as the English walnut, may be seen growing in nearly every county in the state of California. The commercial production of nuts, however, is centered mainly in southern California; in Los Angeles, Orange, Ventura, Santa Barbara, Riverside, and San Bernardino counties. In the central part of the state walnut culture is becoming important—in Santa Clara, San Joaquin, Contra Costa, Lake, Napa, Tulare, and Sonoma counties.

At the present time, there are approximately 125,000 acres of walnut trees of various ages within the state.

During the past decade walnuts have been one of the most staple and at the same time one of the most profitable crops which could be grown on such land and in such locations as are adapted to this crop.

The importance of walnuts as an article of commerce is shown in table 1. The record of importation of walnuts from abroad together with the production in this country may be compared. The increasing importance is shown of both the imported and domestic walnuts as a source of food in this country.

Inasmuch as the proportion of imported shelled nuts to those imported in the shells has increased greatly during the past decade, it is necessary to transpose all tonnage figures to the same basis. Otherwise the totals are not comparable. The total tonnage for each year is therefore stated in terms of walnuts in the shell, the kernel tonnages being transposed into terms of unshelled nuts containing 45 per cent edible portion.

An ordinary sample of commercial domestic nuts may be expected to contain 45 per cent edible portion. It should not be inferred from this that the transposed tonnage on the basis of 45 per cent edible portion represents the tonnage of walnuts which was cracked to obtain the imported kernels. The calculations are made in this way

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merely to show approximately the tonnage of domestic nuts for which the imported kernels act as a substitute. The actual tonnage of foreign nuts which was cracked to obtain the kernels as stated in table 1 was more nearly in the proportion of 3 to 1, as 32 per cent is more nearly the edible portion found in many of the European "cracking varieties."

Walnuts, formerly looked upon as a holiday luxury, are becoming more and more a food to be used the year through in the average household.

In table 1, column 6, the production of merchantable nuts in California is shown. It is apparent that there is a marked fluctuation in production from year to year according to the favorableness of the seasons. The trend in production obviously cannot be obtained by comparing the production for a single year with another single year. The production in 1919, for example, has been exceeded only twice during the nine years which have followed, and in only one year has the tonnage exceeded the 1919 production by a notable amount. This, however, does not give a true picture of the trend of production. If the average of the four-year period, 1915 to 1918 inclusive, is compared with the average production during 1925 to 1928 inclusive, a leveling effect will be obtained by averaging four years' production together in each instance. This average annual production in the first instance is 16,034 tons and the second instance is 26,841; this may be taken as a fairly reliable indication of an increase of 67 per cent during the past decade.

The importations recorded in columns 2 to 5 inclusive of table 1 show a notable increase during the decade heretofore mentioned. The average annual imported tonnage of unshelled walnuts (column 5) has advanced from 22,059 tons to 34,784 tons, or an increase of 58 per cent, during the decade just past. This may not be a true picture of the trend of importations, however, because of the restriction of available shipping facilities during the World War. For this reason the figure 58 per cent is probably somewhat inflated.

Consumption in the United States.—Taking the four years just past as a basis, the consumption of walnuts in the United States, as shown in columns 5 and 10 of table 1, has been divided between domestic production and importations in the proportion of 47 to 53. This is graphically shown in figure 1. On the basis of the edible portion of the nuts, the domestic production in the United States is slightly less than half the total consumption.

In terms of walnuts in the shell, 45 per cent edible portion (page 5) the total annual consumption of walnuts in the United States has

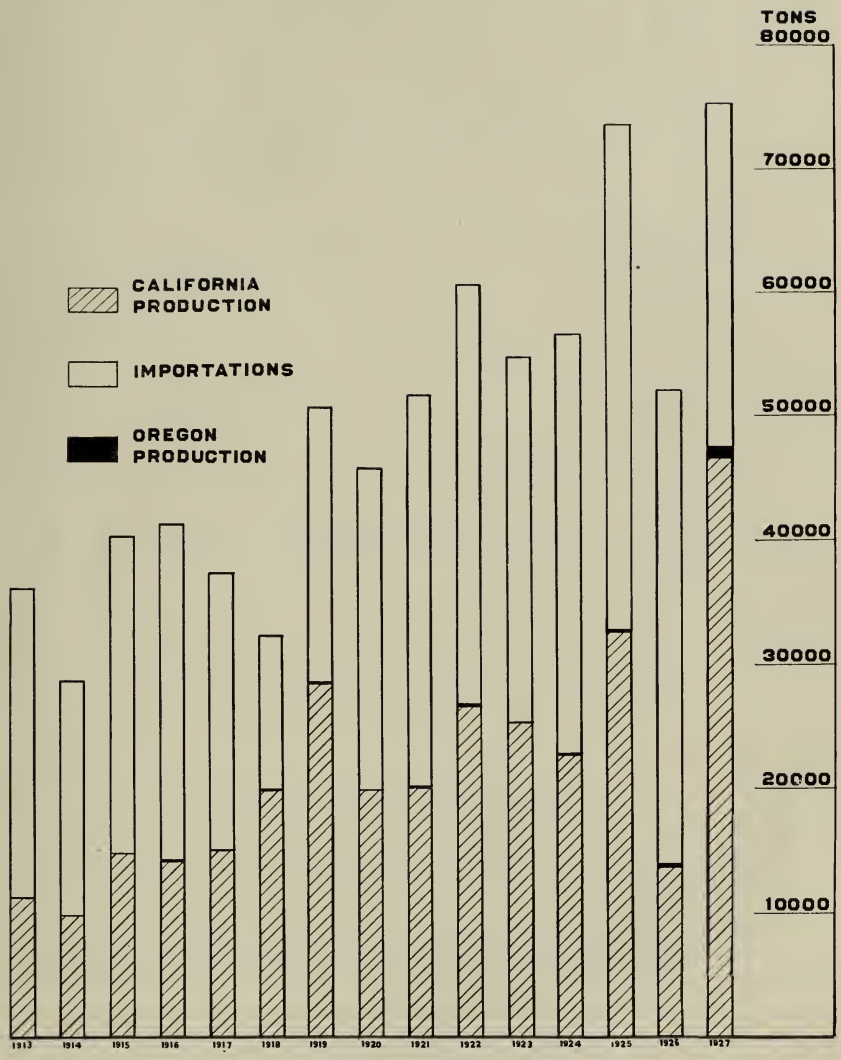


Fig. 1.—Annual consumption of walnuts in the United States. Domestic and foreign tonnage sold as walnut *kernels* has been converted to the basis of unshelled nuts, 45 per cent edible portion, and added to the original tonnages sold as unshelled nuts.

TABLE 1

TOTAL ANNUAL WALNUT IMPORTS INTO UNITED STATES AND UNITED STATES PRODUCTION IN TONS

Year	Imports				Total production merchantable nuts in Calif.	Kernels sold by Calif. Walnut Growers Assoc.	Kernels sold by Calif. Walnut Growers Assoc. converted to nuts 45 per cent edible	Production in Oregon	Total consumption in the United States
	Shelled	Converted into unshelled at 45 per cent edible	Unshelled	Total in terms of unshelled					
1	2	3	4	5	6	7	8	9	10
1913	5,051	11,224	13,698	24,922	11,189			114	36,225
1914	3,890	8,644	11,234	19,878	8,890			90	28,858
1915	6,602	14,670	10,938	25,608	14,817			150	40,575
1916	6,992	15,536	11,447	26,983	14,340			148	41,471
1917	6,129	13,619	8,589	22,208	15,123			183	37,514
1918	4,854	10,786	1,652	12,438	19,857			203	32,498
1919	5,131	11,401	10,617	22,018	28,448			237	50,703
1920	7,909	17,576	8,036	25,612	19,997			214	45,823
1921	6,666	14,812	16,707	31,519	20,068			204	51,791
1922	8,105	18,009	15,914	33,923	25,011	774	1,719	275	60,928
1923	9,171	20,378	9,107	29,485	24,405	394	875	255	55,020
1924	9,599	21,330	12,551	33,881	21,405	577	1,281	230	56,797
1925	11,878	26,395	14,003	40,398	28,874	1,752	3,893	367	73,532
1926	11,554	25,675	12,559	38,234	11,740	794	1,764	480	52,218
1927	9,787	21,748	6,070	27,818	41,751	2,250	5,000	770	75,339
1928	9,705	21,567	11,117	32,684	25,000	1,750	3,889	1,000	62,573
Average 1915–1918, inclusive	6,144	13,675	8,156	21,809	16,034			171	38,014
Average 1925–1928, inclusive	10,731	23,846	10,937	34,783	26,841	1,636	3,636	656	65,915

ranged between 45,000 and 75,000 tons annually during the past few years. The consumption per capita has increased from approximately 0.745 of a pound (12 ounces) annually during the four-year period 1915 to 1918 inclusive to 1.110 pounds (17½ ounces) as an average of the last four years 1925 to 1928 inclusive. This amounts to 49 per cent increase in per capita consumption during the decade just past. The trend of the annual consumption of walnuts per capita in United States is shown by figure 2.

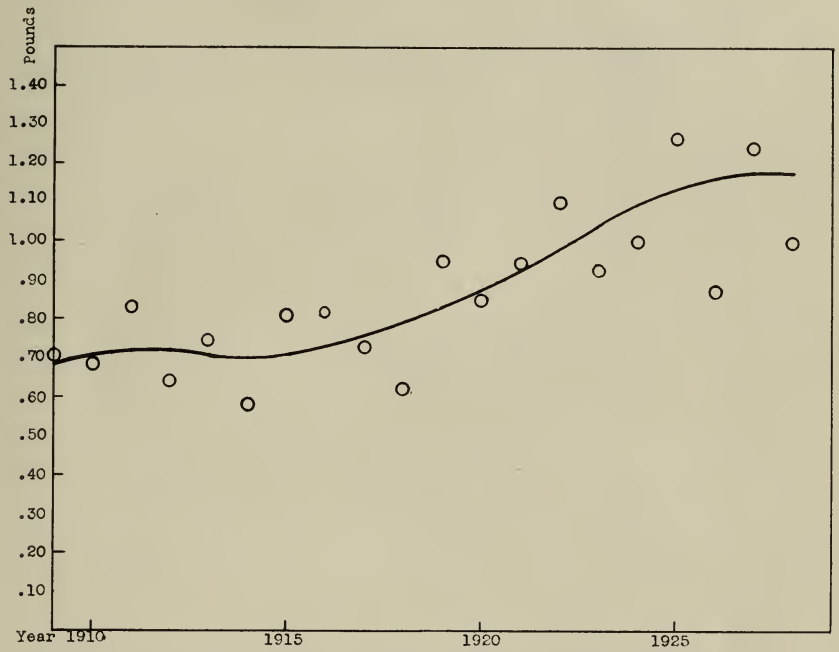


Fig. 2.—Trend of the annual walnut consumption per capita in the United States. Calculated from data of figure 1.

Returns to Be Expected.—The reasonable returns per pound of nuts which may be expected from a walnut grove may be forecast with some degree of confidence by a study of the trend in prices during the past. If such a study is to be put on a sound basis, the figures used must represent the average price per pound received by the growers for their total crop. The figures showing the wholesale market price per pound of certain of the higher-grade classes, after the nuts have been processed and packed, obviously give an erroneous and inflated value when used for the farm price. When such values are used to inflate the price of walnut-grove development subdivisions, the final result amounts to obtaining money under false pretenses.

TABLE 2

SHOWING RELATIONSHIP BETWEEN OPENING PRICE OF GRADED WALNUTS AND NET ORCHARD-RUN PRICE

Year	Opening price	Range of net orchard-run price in 19 local packing houses	Total pounds (thousands)	Total value net to grower	Value per pound net to grower orchard-run	Ratio of orchard-run to opening price, per cent	Per cent of total crop included in data—both seedling and budded walnuts
1	2	3	4	5	6	7	8
SEEDLING WALNUTS							
1922	$0.225	$0.1456–$0.1894	23,994	$4,215,215	$0.1757	78.08	
1923	.220	.1377 .1899	22,449	3,945,913	.1757	79.86	
1924	.250	.1579 .2079	18,531	3,549,437	.1915	76.60	
1925	.240	.0665 .1913	28,193	4,386,421	.1556	64.83	
1926	0.280	0.1260 0.2060	9,122	1,671,767	0.1833	65.46	
Total or average for 5 years			102,228	$17,768,750	$0.1737	71.48	
BUDDED WALNUTS							
1922	$0.26	$0.1479–$0.2274	8,515	1,667,180	$0.1958	70.30	62.72
1923	.26	.1712 .2266	8,638	1,771,229	.2050	78.86	61.48
1924	.29	.1779 .2530	9,028	1,992,586	.2207	76.11	60.73
1925	.29	.1117 .2312	16,060	2,971,672	.1850	63.80	67.52
1926	0.32	0.1700 0.2520	7,098	1,600,408	0.2254	70.45	60.06
Total or average for 5 years			49,340	$10,003,047	$0.2027	71.37	

During the packing process the dirt, culls, small nuts, and medium-sized nuts are separated, for example, from the large nuts. The culls and small nuts may amount to from 20 to 40 per cent of the total door deliveries. The culls may sell for only 30 per cent and the small nuts only 70 to 75 per cent of the value of the large sizes. From this it is clear that the price of nuts as delivered to the packing house, commonly known as "*orchard-run* grade" is bound to be notably and consistently lower than the market price of the large graded nuts.

. The price of orchard-run nuts net to the grower is only arrived at after all costs for grading, packing, and selling have been deducted. This will then give a true value of the crop as it comes from the drying yards f.o.b. the packing-house platform. This value per pound should in our opinion be the basis for comparing the price of nuts one year with another, and one district with another, or in reviewing past average prices of all districts, as they may enable us to forecast the reasonable expectations of the future.

In order to find the average price which has been received by the grower for orchard-run nuts during several years, and in various districts, a special study of this subject was made in cooperation with the California Walnut Growers Association. Data were obtained from nineteen packing-houses located in the following counties: Los Angeles, Orange, Riverside, Santa Barbara, San Bernardino, and Ventura; showing the total tonnage received from, and the total money paid to, their respective members. The districts covered by the local packing houses are considered typical of southern California.

The data from all districts considered as a whole are presented in table 2. A distinction is made between seedling and budded nuts because of the consistent differential in price between these two types. The "opening price" of the large-sized nuts in each of these respective types is shown in column 2 for five years. The lowest and highest net price per pound per year for orchard-run nuts paid by the nineteen locals to their members is shown in column 3. The total weight of the door deliveries of ungraded nuts is shown in column 4. The money paid to the growers recorded in column 5 represents the net return after all grading, packing, and selling costs have been deducted. If the money received, shown in column 5, is divided by the number of pounds for each year, as shown in column 4, the resultant figures in column 6 will show the average net return per pound to the grower for the orchard run nuts f.o.b. the packing-house platform.

It is of interest to obtain also the average return of all nuts from all the houses for the five-year period, which shows that the seedlings sold for $0.1737 a pound and the budded nuts for $0.2027 a pound.

The ratio of this orchard-run price to the "opening price" of the best-grade large nuts both of seedlings and budded nuts is shown in column 7. This ratio has varied during the five years from 64.83 per cent to 79.86 per cent for seedlings and from 63.80 per cent to 78.86 per cent for budded nuts.

The average for all years shows that the two classes of nuts have returned to the grower practically the same proportion of the opening prices herein noted, namely 71 per cent of the best grade of nuts of each respective class.

With this figure of 71 per cent as a basis of calculation we can calculate the most probable average net return per pound received for orchard-run nuts during the past sixteen years. These data are presented in table 3, and although this does not show the actual return for the entire state for any one year, and the prices for all years except 1922 to 1926 inclusive are arbitrarily arrived at, it is, nevertheless, believed that these data represent more nearly the actual returns which were realized than the quotation of any price per pound for the graded product.

TABLE 3

ESTIMATED ORCHARD-RUN PRICE OF WALNUTS*

Year	Seedling	Budded	Year	Seedling	Budded
	cents	*cents*		*cents*	*cents*
1909	8.16	10.65	1919	22.36	24.14
1910	10.65	12.42	1920	15.97	18.10
1911	9.94	11.71	1921	17.37	19.88
1912	9.94	11.71	1922	17.57†	19.58†
1913	11.36	13.49	1923	17.57†	20.50†
1914	11.71	14.20	1924	19.15†	22.07†
1915	9.65	12.07	1925	15.56†	18.50†
1916	11.00	13.49	1926	18.33†	22.54†
1917	14.27	17.11	1927	14.91	17.75
1918	19.88	22.36	1928	18.46	20.23

* Orchard-run price is taken to be 71 per cent of opening price as shown in table 2.

† 1922 to 1926 orchard-run prices from table 2, which are used as a base from which to calculate the orchard-run prices in this table.

The fluctuation of this most probable price per pound for budded walnuts is shown by figure 3. The trend of prices for several commonly grown agricultural crops is of interest to compare with the walnut prices. Whereas walnuts experienced the inflated valuation during the World War in common with most commodities, there has been a more stable price placed on walnuts since 1921 than in the case of many farm products, particularly beans and oranges.

Income Derived from Walnuts.—In order to assist the beginner in considering the probable profits which have been derived from growing walnuts, table 4 has been prepared.

The average yield for the state varies from year to year. Numerous statistical publications indicate that a ten-year average yield for bearing orchards is approximately 800 pounds per acre. This yield will, no doubt, seem rather low to many experienced growers. It should be borne in mind, however, that the average production per acre for the state as given above is not a true average of the profitable walnut acreage of the state. This figure is based on all walnut plantings eight years old and over and includes that acreage which, though planted to walnuts, is not suited to walnut culture, due to climatic or soil conditions.

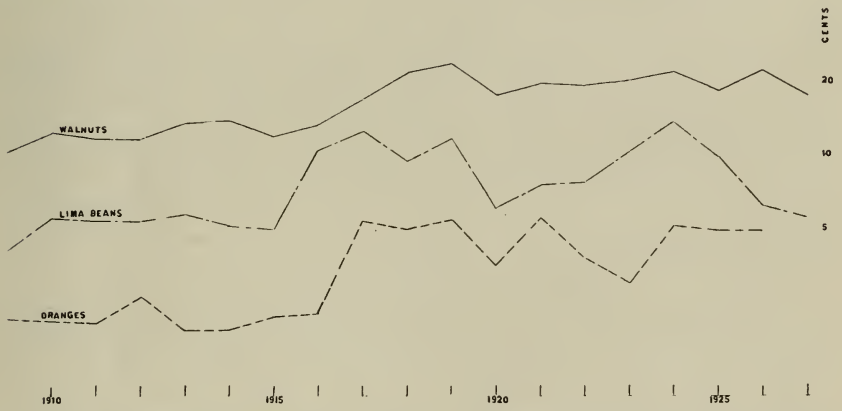


Fig. 3.—Annual fluctuation in prices per pound of walnuts, Lima beans, and oranges. The theoretical orchard-run price of walnuts was determined as noted in table 2. Lima beans and oranges f.o.b. prices.

It should also be born in mind that the *average* production for a period of ten years of many good groves is considerably lower than the *occasional* yield of the same groves. Blight, frost, heat, and other natural agencies make rather frequent inroads in the prospective crops. Groves which have *averaged* 1,500 pounds per acre for a period of ten years are rare, and those which have averaged 2,000 pounds or more are extraordinary. An average annual yield of 1,200 pounds per acre may be used to indicate yields which would be safe for business estimates.

Hunt[3] writes that "A competent farmer should expect, and no one should undertake to farm unless he may reasonably expect, to produce 50 per cent more than the average. On this basis, the gross income per annum may be estimated at 25 per cent of the capital

[3] Hunt, T. F. Suggestions to the settler in California. California Agr. Exp. Sta. Cir. 210:4. 1919. (Out of print.)

invested. . . . . This does not mean that every legitimate farm enterprise will, or should bring in just 25 per cent of the capital invested. This statement is only meant to give one a 'yard stick' with which to measure any definite farming enterprise."

TABLE 4

ESTIMATE OF AVERAGE RETURNS FROM WALNUT GROVES BASED ON THE AVERAGE OF ORCHARD-RUN PRICES FOR THE PAST TWENTY YEARS.

(SOUTHERN CALIFORNIA)

	Seedling walnuts			Budded walnuts		
	Low-producing groves	Safe for business estimate	Possible but extraordinary	Low-producing groves	Safe for business estimate	Possible but extraordinary
Yield in pounds per acre	800	1,200	2,000	800	1,200	2,000
Value of property*	$470.08	$705.12	$1175.20	$548.00	$822.00	$1370.00
Gross income†	$117.52	$176.28	$293.80	$137.00	$205.50	$342.50
Annual cost of operation‡	$ 92.34	$ 92.34	$ 92.34	$ 92.34	$ 92.34	$ 92.34
Harvesting and curing at $0.0188 per pound‡	15.04	22.56	37.60	15.04	22.56	37.60
Total charge against crop§	107.38	114.90	129.94	107.38	114.90	129.94
Net income per acre¶	10.14	61.38	163.86	29.62	90.60	212.56
Interest at 6 per cent on valuation‖	28.20	42.31	70.51	32.88	49.32	82.20
Profit per acre	*—$18.06*	$19.07	$93.35	*—$3.26*	$41.28	$130.36
Interest returned to capital over and above 6 per cent		2.7%	7.94%		5.02%	9.51%

* Hunt, T. F. Suggestions to the settler in California. California Agr. Exp. Sta. Cir. *210:* 4, 1919. [Basis of calculations, "gross income per acre per year may be estimated at 25% of capital invested." Explained on p. 11.]

† Based on the estimated average *orchard-run price* of $0.1469 per pound for seedling walnuts and $0.17125 per pound for budded walnuts for the years 1909 to 1928 inclusive. Explained on p. 10.

‡ From Hearing before the House of Representatives Committee on Ways and Means, Seventieth Congress, Second Session, Schedule 7, No. 18, Jan. 26, 1929.

§ Includes irrigation, pruning, cultivation, depreciation, insurance, taxes, and a reasonable charge for owner's supervision.

¶ Gross return minus all expenses.

‖ The rate of 6 per cent is used here to charge against the grove as the return which might have been made had the owner invested in securities rather than a walnut grove.

The value of the property set forth in table 4 has been arrived at by Hunt's method of estimating the average gross income as 25 per cent of the capital invested. Such a valuation is somewhat lower than that set forth in table 9. The figures in table 9 are based upon

the owner's estimate of the *exchange valuation* of the property. This exchange valuation may be concerned with many other factors aside from net returns on the property. It may include proximity to schools, highways, cities, desirability of the climatic conditions, etc. All of these factors are valuable assets without being effective in maintaining a profitable walnut grove. Those who may be interested in engaging in walnut production should consider the situation from all viewpoints.

Acreage.—A review of the status of the industry by considering importations, domestic production, and prices realized from the crop during the past, should also be accompanied by a consideration of the area of land devoted to this crop. The trend of walnut prices and the trend of newly planted walnut acreage are in some measure dependent on each other. When nuts are high priced, the planting of walnut groves is stimulated. As prices decline the increase in acreage is retarded, and the bearing acreage is reduced by pulling out unprofitable groves.

TABLE 5

Estimated Bearing Walnut Acreage*

Year	Acreage	Year	Acreage	Year	Aacreage
1914	34,138	1919	50,900	1924	68,572
1915	34,453	1920	58,963	1925	69,629
1916	35,379	1921	61,781	1926	71,779
1917	45,687	1922	65,530	1927	75,307
1918	48,520	1923	66,951	1928	83,252

* From: Kaufman, E. E. California Crop Report for 1927. California State Dept. Agr. Special Publication *86:* 1-63. 1928.

Table 5 shows the estimated bearing walnut acreage in California for the years 1914 to 1928 inclusive. The total acreage, including non-bearing and bearing, is a considerably larger figure. The California Cooperative Crop Reporting Service makes the following forecast as to the increase in bearing acreage:

The estimated bearing acreage for 1928 is 83,252 acres and will be 89,000 in 1929; 95,900 in 1930, and 104,000 in 1931.

It is estimated that the bearing acreage will increase approximately 6,000 acres a year for the next three years.

It should be borne in mind, however, that a part of the present non-bearing acreage will never be allowed to come into bearing due to the fact that it is planted in localities that are better fitted for

other purposes. Also there are large acreages of walnuts planted in unproved districts and in districts where a city already threatens their existence. The future of these plantings is uncertain as to eventual production and there is reason to believe that a considerable percentage of this acreage will not appreciably affect the state production.

In contrast to the rapid planting of walnuts in certain districts as has been heretofore noted, there is a marked decrease in bearing acreage in some of the southern districts. This decrease may be caused by one or more of the following factors which have been effective in the past and are apparently still operative.

Increasing land values due to the large profits realized in citrus production have been responsible for pulling out large acreages of seedling walnuts to make room for planting Valencia orange trees.

Subdivision possibilities are responsible in no small way for the abandoning of walnut acreage near cities.

In certain districts the water supply has been found to be unsuited to walnut culture and large acreages may possibly be pulled out to devote the land and water to crops better suited to the existing conditions.

Pest control is becoming an increasingly costly operation in some localities, and this is causing the replanting of former walnut acreage to crops not subject to the pests in question.[4]

Length of Life of Walnut Trees.—The limit of the profitable length of life of a walnut grove cannot be determined from experiences in California. Provided the soil, climatic, and water conditions are well suited to this crop, the trees may continue to thrive and produce satisfactory crops for a long period. Groves which are now 40 to 45 years old are still among the most prolific in the state. Groves in which the trees are planted 60 feet each way may be expected to grow longer without deterioration than groves where the trees are planted closer and thus severely compete with each other.

The writings of travelers in Asia and Europe frequently describe walnut trees from one to two hundred years old. The continued health and profitableness of many of the present day California walnut groves until they are a century old seems a reasonable expectation. Much depends, as will be related later, upon the soil, drainage, and general climatic conditions.

[4] For a more detailed discussion of the economic situation, see: Erdman, H. E. and W. U. Fuhriman. Walnut supply and price situation. California Agr. Exp. Sta. Bul. 475:1–60. 1929.

Profitable Bearing Age of Young Trees.—The young walnut grove may be expected to bear profitable crops by the time the trees are 6 to 10 years old, according to the variety, the number of trees planted per acre, and the natural conditions surrounding the grove. The cases noted in table 6 may illustrate the possibilities of early production in young walnut groves.

In considering this table one should keep in mind that each of these plantations is growing under good natural and cultural conditions, and thus, without doubt, is considerably above the average. In projecting a business enterprise, the yields shown may be looked upon as approaching the maximum possibilities, and should, therefore be discounted 25 to 50 per cent to reach a figure which may reasonably be expected to prevail under average conditions. Again, the figures here presented are of little value in making comparisons between the three varieties in question, as no two varieties were of the same age the same season.

TABLE 6

Average Yearly Production Per Tree of Young Walnut Groves Growing Under Especially Good Conditions

Year	Variety					
	Placentia		Chase (Ungraded nuts at harvest)		Ehrhardt (Ungraded nuts at harvest)	
	Age of grove, years	Yield in lbs.	Age of grove, years	Yield in lbs.	Age of grove, years	Yield in lbs.
1915	7	22*			10	80
1916	8	27*			11	76
1917	9	44†	5	18	12	79
1918	10	43†	6	35	13	81
1919	11	104†	7	72	14	117
1920	12	82†	8	43	15	98

* Pounds of cured and ungraded nuts at harvest.
† Pounds of uncured and ungraded nuts at harvest.

Although the cultural and natural conditions in all three groves were favorable, the plantings are several miles apart and conditions were not identical. Certain seasons are particularly favorable to crop production. The year 1919 was characterized by especially abundant crops of walnuts. This year was followed in many cases by lighter crops in 1920, although the young trees were one year older and had a greater bearing surface.

CLIMATIC LIMITATIONS

The chief climatic limitations of the walnuts are frosts in spring and fall, and extreme heat in summer.

Frost Injury.—Low frosty sites should be avoided for walnuts. A temperature of even 2 or 3 degrees below freezing (32° Fahrenheit) for a period of an hour or more will usually kill a large percentage of the young walnut flowers, or the small nuts. During 1920, late spring frosts during the second week of April reduced the walnut crop to a great extent in several of the inland valleys. In one instance under careful observation the absolute minimum temperature recorded by a reliable thermometer was only 29° F, yet it was estimated that 50 per cent of the crop was destroyed. During this period apricots and the earlier-blooming cling peaches in adjacent orchards were about the size of green peas, and experienced little or no injury.

On the morning of April 6, 1921, a minimum temperature of 27° F was experienced by a seedling walnut grove in which the majority of the trees were in full bloom. This temperature prevailed for about an hour and apparently destroyed nearly the whole crop, except in the tops and centers of the trees, where an occasional cluster of blooms escaped injury.

As a general rule, the late-blooming varieties are less liable to injury from the late spring frosts than the earlier-blooming soft-shell types. During the spring of 1915, however, walnut twig tips and young nuts were killed during the first week in May on some of the low sites in Los Angeles County. With a frost as late as May, the late-blooming varieties may suffer more injury than the earlier ones, as the young nuts (one-half inch or more in diameter) of the early-blooming varieties will stand lower temperatures at this time than the blossoms of the late varieties. The late-blooming varieties do not, therefore, always escape late spring frosts. It is better to avoid planting walnuts on land which is considered too frosty for peaches. The walnut varieties of the soft-shell type bloom about the same time as the Bartlett pear, but their flowers are not nearly so resistant to frost injury.

Young twig growth is especially subject to injury by early fall frosts. The injury may not be apparent to the casual observer until the following spring, when the tree will fail to leaf out on the injured portion of the past season's growth. This type of injury is more fully

treated under the subject of die-back. It may suffice to explain here that early fall frosts prematurely stop the final ripening process of the twigs by killing the leaves. Such injured leaves will usually fall off within a week after the frost injury, whereas they might otherwise have functioned normally for a month or six weeks longer. The bare, immature twigs dry out rapidly and sunburn on the south side during the winter months, dying back several inches, or possibly several feet, to the more mature wood, which has been able to withstand the low temperature without injury.

When the tree is dormant, the absolute minimum temperatures of winter, during January and February, apparently have very little to do with its welfare. This is especially true of the French varieties. Trees of the Mayette and Franquette varieties have grown for some years without severe winter injury along the west side of the Wasatch Mountains north of Salt Lake City, Utah, where the minimum temperature occasionally reaches −5° F.

Heat Injury.—The chief injury to the walnuts during the extreme hot weather of the summer months is the sunburning of the nuts located on the outsides, tops, and south sides of the trees. Such burned nuts usually become 'blanks' if the injury occurs during June or July. If the sunburning takes place when the nuts are more fully developed, in August, they may be salvaged as culls, a portion of which may have edible kernels. In mild cases of sunburn injury a small part of the husk may stick to the shell or may only stain it, causing the nut to be graded out as a cull. The kernels of such nuts may be of good quality, although it is likely that there will occur among them a high percentage of amber and black kernels. Partly shriveled and moldy kernels may be expected among this class of nuts. Nuts on trees growing on a deep loam soil withstand the extreme heat, without burning, much better than nuts on trees growing on a shallow or sandy soil with less moisture available.

A temperature of 100° F, or above, accompanied by low humidity will usually cause walnuts to sunburn if they are exposed to the direct rays of the sun. This temperature, or higher, often occurs in many of the inland valleys during the summer months. Under such conditions the crop is always injured more or less by sunburn.

At the present time walnut groves have not become so productive in the inland valleys, which experience frequent summer days with maximum temperatures of 100° F and over, as they have been nearer the coast, where the weather is characterized by a smaller daily range and a lower maximum temperature. Varieties especially

selected for the hotter sections may tend to correct this difficulty in the future. In the past, most of the walnuts planted inland have been of the same varieties as those which were originally selected for the coastal regions. Varietal adaptation is more fully treated under the heading of varieties.

At present, walnut culture is most successful in the sections of the state which are characterized by a long growing season free from frosts and where the daily range in temperature is not great, the absolute maximum seldom goes above 100° F, winter temperatures are moderate, and the humidity is high especially during the summer. Sudden changes in temperature, such as occur in the desert regions, seem to be decidedly detrimental to the growth of the walnut tree. The localities where favorable climatic conditions occur are indicated by the largest walnut shipping centers in the state—Santa Ana, Whittier, Puente, Saticoy, San Jose, and Santa Barbara.

SOIL REQUIREMENTS

Depth and Character of Soil.—The success of walnut culture is dependent upon favorable soil conditions to a greater extent than that of many other tree crops. A well-drained deep silt loam soil containing an abundance of organic matter, free from a high or fluctuating water table, hardpan, sandy subsoil, and alkali, is essential for a first-class walnut grove. Shallow soils underlain by a hardpan, sand layer, or an impervious clay stratum within 5 or 6 feet of the surface will produce only a short-lived, recond-rate, walnut grove. Such groves are frequently stunted in growth, subject to 'yellows,' and are only fair producers.

There are a few moderately successful groves growing in fine silt soil underlain with fine sand within 4 or 5 feet from the surface, but such properties require especial skill in culture and irrigation. A walnut grove growing on such soil has a considerably lower intrinsic value than one growing in good soil if the other environmental factors are equal.

Very light sandy soils are usually unsatisfactory, producing slow-growing, stunted, poor-yielding trees. On such soils the nuts are very subject to sunburning.

One should not judge the soil conditions entirely by the surface soil. The nature of the subsoil is of great importance.

Very heavy adobe soil and clay loam underlain by adobe soil are not well suited to walnut groves. The trees on such soils are usually

somewhat stunted, and make very little growth of fruit wood in the tops when mature. Heavy soils are difficult to cultivate, and it is hard to obtain a deep penetration of irrigation water, which is essential to good walnut culture. Such soils frequently contain amounts of alkali salts which are harmful to walnuts, and their leaching by any system of irrigation is very difficult.

Drainage and Alkali Injury.—A water table within 9 or 10 feet of the surface of the soil may make it impossible to maintain a profitable walnut grove. Most of the high water tables in arid regions carry more or less alkali[5] in solution. The mere presence of water within 9 or 10 feet of the surface is usually only part of the difficulty, the alkali present being of greater concern, for the deep-rooted trees obtain a portion of their water from this water table, and may be injured by the salts therein, even though there is a seemingly sufficient layer of good soil above the water. In Orange County an old grove was practically ruined by a rise in the water table to within 9 feet of the surface. This water contained 700 parts per million of salts. The water raised approximately 6 feet by capillary action in the soil; thus there was only a 3-foot depth above the standing water which was not impregnated with alkali salts. In several groves in Ventura County walnut trees were severely injured by the presence of an alkali ground water 9 to 13 feet from the surface. When the trees were planted 20 years ago in this district, the water was at least 30 feet from the surface. It is difficult to place a definite safe boundary beyond which injury from a high water table is not likely to occur.

Apparently, quite as much depends upon the nature of the water as upon the actual depth from the surface, within the root zone. The rainfall, irrigation practice, the nature of the soil and of the irrigation water may also greatly influence the suitability of land with a high water table for walnut culture.

Several groves severely injured by an alkali water table have been observed to improve to some degree after the installation of tile drainage. Drains should be laid 6 to 7 feet deep to improve conditions effectively. After the installation of tile drains, relatively frequent and only moderate amounts of irrigation water should be applied. By following such an irrigation practice the salt concentration in the upper six feet of soil will be reduced to a point which the walnuts will tolerate.

[5] For a discussion of alkali in the irrigation water see page 22.

The groves which have been tile-drained and judiciously irrigated have not returned to a normal condition, however. Some alkali injury[6] is noticeable among them, and although the crop production has returned to a profitable commercial tonnage, it seems unlikely that a first-class grove can be maintained under such conditions.

Groves which had been somewhat injured by poor drainage conditions, even though tile-drained, have shown a marked improvement after being intercropped with alfalfa[7] for several years. The cause of the beneficial effect of such a crop association is not fully understood, but the improvement following such plantings has been apparent in so many instances that the results cannot be explained by mere chance. Alfalfa will thrive on alkali soil conditions far beyond the tolerance of walnut trees. The deep-rooted alfalfa plants, no doubt, use up a portion of the alkali salts present. The presence of the alfalfa makes the flooding of the land by irrigation water more practicable, and probably results in a more uniform downward movement of soil moisture with less liability of salt concentration in localized areas, a condition which is often typical of furrow irrigation. The shading of the soil surface by the alfalfa reduces the surface evaporation and thus hinders the rise of capillary water from the water table below. It is impossible, however, to state which of the above-mentioned factors are most potent in causing the beneficial effect.

Exceptions to the rule of injury resulting from a high water table are very rarely found. Such exceptions are usually orchards subirrigated by a natural flow of water from the hills, or natural stream beds. The good appearance of the trees in several of these rare examples show that the ground water contains no alkali, or an exceedingly small amount of it, a condition which is exceptional in the high water tables in irrigated areas of the arid west.

WATER REQUIREMENTS

In most of the California walnut districts, irrigation is necessary. The amount of water to be applied and the seasons of application naturally depend upon the rainfall, the amount of evaporation, the nature of the soil, and other factors. The walnut tree cannot be expected to yield profitable crops unless furnished with an abundant supply of water during practically the entire year.

[6] For a more detailed discussion of the characteristics of alkali injury see page 24.

[7] For a discussion of injurious effects of alfalfa on normal groves see page 82.

Amount of Irrigation Water Necessary.—From 12 to 24 acre-inches per acre[8] of irrigation water are usually applied to bearing walnut groves. (See table 8 for conversion of miners' inches to acre-inches.) Closely planted and old bearing groves will require more water than young groves, or those with fewer trees to the acre, other things being equal.

Table 7 shows the average rainfall in several of the sections where walnuts are grown.

TABLE 7

Normal Rainfall in Several Walnut-Growing Sections

Place of observation	Normal annual rainfall in inches	Place of observation	Normal annual rainfall in inches
Los Angeles	15.55	San Diego	9.70
Napa	24.16	San Jose	15.08
Pomona*	19.2	Santa Rosa	31.15
Riverside	11.05	Stockton	14.25
Santa Barbara	18.16	Tustin	13.15

* Average of eight years, 1913 to 1920, inclusive.

TABLE 8

Converting Stream Flow, Measured in Miners' Inches, to Acre Inches

Hours	Miners' inches									
	1	2	3	4	5	6	7	8	9	10
1	0.0198	0.0396	0.0594	0.0792	0.0990	0.1188	0.1386	0.1584	0.1782	0.1980
2	.0396	.0792	.1188	.1584	.1980	.2376	.2772	.3168	.3564	.3960
3	.0594	.1188	.1782	.2376	.2970	.3564	.4158	.4752	.5346	.5940
4	.0792	.1584	.2376	.3168	.3960	.4752	.5544	.6336	.7128	.7920
5	.0990	.1930	.2970	.3960	.4950	.5940	.6930	.7920	0.8910	0.9900
6	.1188	.2376	.3564	.4752	.5940	.7128	.8316	0.9504	1.0692	1.1880
7	.1386	.2772	.4158	.5544	.6930	.8316	0.9702	1.1088	1.2474	1.3860
8	.1584	.3168	.4752	.6336	.7920	0.9504	1.1088	1.2672	1.4256	1.5840
9	.1782	.3564	.5346	.7128	.8910	1.0692	1.2474	1.4256	1.6038	1.7820
10	.1980	.3960	.5940	.7920	0.9900	1.1880	1.3860	1.5840	1.7820	1.9800
11	.2178	.4356	.6534	.8712	1.0890	1.3068	1.5246	1.7424	1.9602	2.1780
12	0.2376	0.4752	0.7128	0.9504	1.1880	1.4256	1.6632	1.9008	2.1384	2.3760

Acre inches

While the amount of seasonal rainfall may be taken as a good indication of the amount of irrigation water necessary to supplement

[8] For a detailed description of the various methods of measuring water on the farm, see: Wadsworth, H. A. Measurement of irrigation water on the farm. California Agr. Exp. Sta. Cir. 250:1–36. 1922.

An acre-inch of water is the quantity of water required to cover one acre to the depth of one inch.

50 southern California miners' inches = 1 cubic foot per second.

1 cubic foot per second = 7.48 gallons per second.

it, it should be borne in mind that other factors, such as frequency, duration, and amount of individual rains, run-off, and season of occurrence, must also be considered, as they influence the proportion of the total precipitation which penetrates into the root zone of the walnut trees. A volunteer growth of annual plants, such as wild oats or mustard, greatly reduces the effectiveness of the rainfall.

Monthly records of the average penetration of rain water into the soil were kept for three years in Riverside County, in a walnut grove growing on a sandy loam soil. The results varied somewhat from month to month, according to frequency, duration, and volume of rainfall. The total seasonal penetration into the soil varied from 4 to 6 inches with an average of 5.2 inches for each inch of rain. The efficacy of many of the light rain storms of one-half an inch in volume and less, is greatly reduced by the evaporation from the surface soil. This in turn is dependent to some degree upon the prevalence of drying winds. The penetration of soil moisture per inch of rainfall will be considerably greater than the above records show during seasons when the storms occur with short intervals between them, or when the individual storms are of uncommonly large volume. The depth of penetration of winter rains in a soil will also depend on its water-holding capacity as well as to some degree on the initial dryness of the soil. For a discussion of this latter side of the problem, see "Frequency of Irrigation," page 75.

The water requirements are higher in the warm inland valleys which are characterized by lower humidity and high temperatures during the growing season, than in most coastal regions, where the summers are cooler and foggy days frequently prevail.

It may safely be said, therefore, that the walnut grove in some of the southern and central inland districts should be provided with a water right of 24 acre-inches per acre per year, during years of normal rainfall, and that from this maximum the requirements diminish until in some individual and exceptional cases in Sonoma, Lake, and Napa counties, walnuts may be grown successfully without any irrigation.

During years of subnormal rainfall the water requirements noted will prove inadequate and provision should be made for a heavy application of water during the winter months. (See "Winter Irrigation," page 66.)

Irrigation Water of Good Quality Essential.—The quality of the irrigation water for walnuts is as important as the quantity. Relatively

small amounts of the alkali salts carried in the water are decidedly harmful to walnut trees. From many observations made during a period of several years, it seems that the walnut tree is the most sensitive to alkali injury of all the orchard trees grown in California. The minimum amount of salts which will prove toxic to walnut trees depends upon so many factors, such as the nature of the soil, the under-drainage, and the rainfall, that it may be impossible to state the exact maximum amount of salt which might be applied with the water without serious injury to the trees. In the districts of heavy rainfall and in well underdrained groves, water of poor quality could no doubt be used longer with less harm to the trees than in the more

Fig. 4.—Effect of application of alkali water. Grove on left used water of high salt content, that on right, good water. (From Bulletin 332.)

arid regions, especially where hardpan exists. It is definitely known that walnut groves have been injured severely by the use of irrigation water containing only 340 parts per million of one or more of the alkali salts.

The particular salts which the water contains may have as great a bearing on the injury as the type of soil and other natural conditions of the orchard. It is impracticable to include a prolonged discussion of the effect of alkali on walnuts in this publication; suffice it to warn the present or prospective wâlnut grower of the importance of a water supply of good quality before continuing or establishing a walnut plantation. It is especially important in projecting new plantings to have the prospective water supply analyzed and an expert

opinion given regarding its suitability, before proceeding to develop the property.

Groves which have been severely injured by irrigation water containing harmful amounts of alkali salt may be expected to recover to a large degree, in fact possibly to a normal condition, after several years use of good water. The length of time necessary for such recovery will depend on several factors aside from the extent of the original injury, such as nature of the soil, subsoil, and drainage conditions, amount of water used, and method of irrigation followed after changing to a good water supply. Several groves have been observed which were so injured that the production had reached nearly zero. After using good water for three years combined with good culture, recovery reached a point of profitable bearing. Figure 4 shows the effect of alkali water on walnut trees.

The detailed characteristics of alkali injury to walnut trees, when common salt is the predominating toxic material, are readily recognized during the latter part of the summer or early fall. At this time the margins of the leaves turn brown. The injury begins at the point of the leaf. The injured area finally spreads to include most of the leaf surface, at which time the leaves drop prematurely. In the case of severe injury causing the leaves to drop as early as August, the trees may leaf out again and blossom in early October.

Normally mature walnut leaves, on the other hand, turn light yellow over the entire surface and do not drop off until the latter part of the autumn season.

VARIETIES[9]

History—The original walnut plantings in California were the hard-shell type of seedling trees. This type was grown as dooryard and roadside trees, before walnuts were planted in commercial orchards.

The history of the commercial walnut culture in California commenced in 1867 when the late Joseph Sexton planted part of a sack of walnuts near Santa Barbara. These walnuts were purchased in San Francisco and were probably imported from Chile. From this original planting came hard-shell and paper-shell types of trees. Among the second generation trees from nuts from this planting came

[9] For a more complete description and history, particularly of the less common varieties, see: Smith, R. E., et al. Walnut culture in California; walnut blight. California Agr. Exp. Sta. Bul. 231:119–398. 1912. Also: Lake, E. R. The Persian walnut industry of the United States. U. S. Dept. Agr. Bur. Plant Indus. Bul. 254:1–110. 11 pl. 1913.

the Santa Barbara soft-shell type of tree which bore nuts in many respects intermediate between the two types which appeared in the original planting. The tree characteristics of this new type were soon recognized to be superior to either of the original types. The soft-shell type of tree grew more vigorously and was more prolific than the other types. Combined with this, the nuts were somewhat larger and had a more desirable thickness of shell than either the hard-shell or paper-shell types.

Seedling trees were grown from the best of the Santa Barbara soft-shell trees, and thus began the early development of the present walnut industry, which was based entirely, in southern California, on seedling trees, the ultimate origin of which traced back to the Sexton planting. During the period of rapid development of the new industry less attention was paid to the parentage of the seedling nursery trees than had been the practice of the pioneer planters. The great demand for trees made it possible to sell trees of unknown parentage, thus many of the seedling groves planted 20 to 25 years after the industry was well started are decidedly inferior to the older groves regarding productivity, size, and vigor of trees, and uniformity and type of nuts.

The collections of trees heterogeneous, regarding both the type of nuts and the bearing qualities, composing the majority of the seedling groves now in existence, finally forced the industry to the propagation of trees by grafting. The most observing growers and nurserymen selected particularly meritorious seedling trees from which to propagate. Thus arose the clonal varieties of walnuts in southern California, practically all of which (except the Eureka) are lineal descendants of the original Sexton planting. Such varieties include the Placentia, Neff, Prolific, Wasson, Ehrhardt, and Chase. During the decade of 1895 to 1905 the propagation of walnuts gradually evolved from the use of seedling trees to a point where the grafted trees were probably planted in the majority of cases. During this time there was a rather general belief that the grafted trees were not likely to be as long-lived or as vigorous as the seedling trees. This belief proved to be entirely unfounded, and by the end of another decade, or by 1915, seedling trees were no longer commercially planted.

In the central part of the state the historical development of the walnut varieties has proceeded independently of the southern part. Although there were hard-shell trees growing in many places through the district, little or no use was made of their progeny in developing the present day varieties of central California.

Many trees and scions of the varieties of walnuts commonly grown in France, were imported into California in the early seventies, by the late Felix Gillet of Nevada City. As a result of Mr. Gillet's efforts, the Franquette, one of the most valuable varieties grown in France, became the leading variety of central California. The Mayette, another French variety, imported by the same means, took a somewhat secondary place in central California. A seedling from the Gillet nursery produced the original Concord tree in Contra Costa County, and from this tree there has developed, by grafting, one of the varieties most extensively planted in central California. The Payne variety also traces its heritage to the varieties from France.

Choice of a variety.—The varieties chosen for planting should be those most marketable, most productive, and best adapted for growing under local conditions. At present there are comparatively few varieties which have won and retained their popularity with the growers and the marketing trade. Many new varieties have been originated in California during the past thirty years, but most of them have been propagated in only a very limited way, and have soon fallen into disfavor, owing to some particular shortcoming. New varieties of the future should be a decided improvement, in some particular, upon our present sorts; otherwise they are not worthy of even limited propagation.

The principal economic advantages which a grafted or budded grove of the best varieties possesses over a seedling walnut grove, are: (*a*) since they are more uniform and of superior quality the budded nuts sell for a higher price than the seedlings; (*b*) a grafted grove is more uniform and has fewer unproductive trees than a seedling grove; and (*c*) certain varieties are less susceptible to blight than the seedlings.

There is no one best walnut variety for planting throughout the whole state. With the varying soil and climatic conditions, the success or failure of a variety may depend upon its adaptation to its surroundings. In reading the discussion of the varieties in the following pages, and the recommendations which are made for planting in the several localities, it should be borne in mind that the observations concerning the varieties have been very general. In many instances an attempt has been made to present the concensus of the opinions of several observers, such as walnut growers, packing house experts, and nursery men, and, although the varieties described seem to be the best for commercial planting at the present time, they may

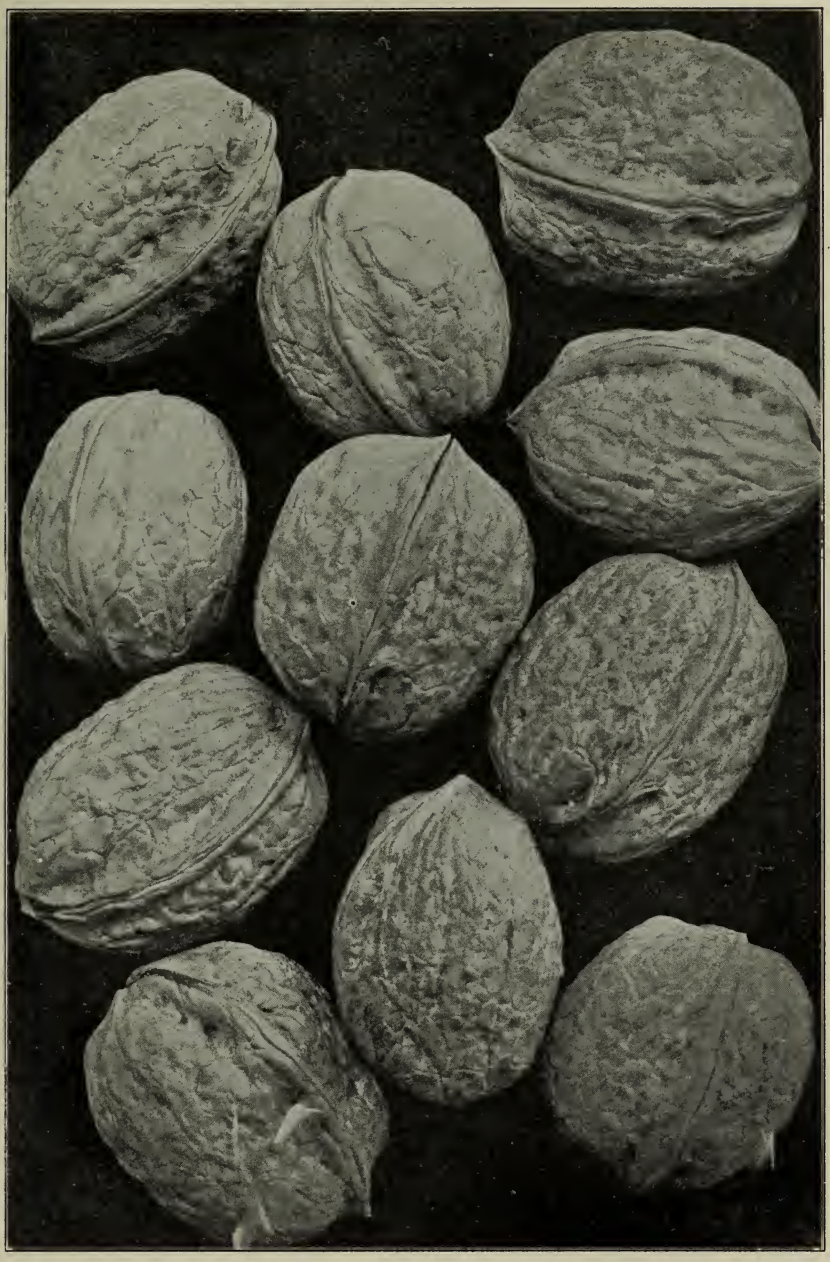


Fig. 5.—Placentia (natural size). (From Bulletin 231.)

be supplanted in the future by varieties entirely unknown at present, or by varieties which may not be highly thought of at this date. The selection of varieties for propagation by grafting and budding has gone on for so short a period that improvements may be confidently expected in the future.

In considering the varieties to plant in a commercial grove, one should select only those which meet the requirements of a first-class commercial nut. It is a decided advantage in the successful sale of the crops to have one community growing only one or at least only a very few varieties, so that a uniform product can be sold in wholesale quantities.

It is essential to have nuts with a heavy shell and a firm seal to withstand the handling in the commercial grading and packing operations without cracking the nuts open. A nut which is partly cracked open soon becomes rancid, and must, therefore, be eliminated from first-class grades. The proportion of kernel to the total weight of the nut in a carefully graded sample of the leading varieties is slightly less than 50 per cent. A *commercial* sample of nuts will not usually show more than 45 per cent edible portion.

Placentia.—(Generally planted in southern California.) The Placentia may, at present, be considered the most commonly planted variety of walnut that has proved successful, commercially, in southern California. At present, most of the nuts sold in the budded grade are of this variety.

The Placentia is one of the most profitable varieties. During 1915 and 1916, however, when blight was very prevalent, many of the Placentia groves blighted as badly as the average seedling groves. Another defect of this nut is its tendency to spring open at the apex if they are dried too rapidly by exposure to the sun during the curing process.

The variety is readily propagated by grafting, making a thrifty, rapidly growing tree. It is usually a precocious producer in southern California and yields very good crops. It is regular in its bearing habits and lacks the tendency of some sorts to bear every other year.

The nut is the desirable size for commercial sale. It has a fairly smooth shell and is oval, though the nuts tend to vary. Some strains are nearly round and somewhat roughened. The nuts are not well sealed. The shell is thin, but strong. The kernel is smooth, plump, and light-colored, and is taken as a standard of quality and appearance for the Budded grade of nuts.

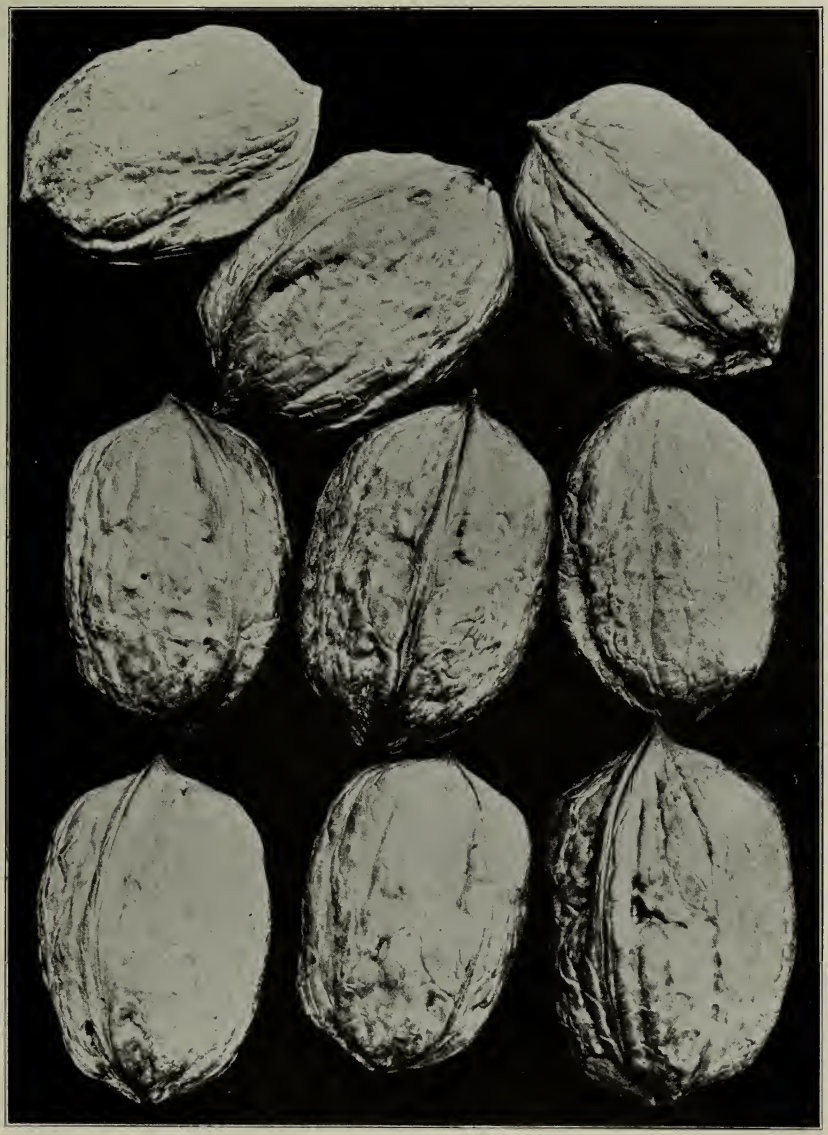


Fig. 6—Eureka (natural size).

In an attempt to learn the cause of the existence of several different types, the ranch where this variety was first propagated was visited during the winter of 1924. In interviewing a member of the family who was present when the early propagation began, it was learned that there were originally *four seedling trees* from which this so-called Placentia Perfection was first propagated. Two of these trees furnished more scions than the others because they were considered somewhat superior as regards productivity and nut characteristics. No attempt was ever made to keep the scions from the four trees separate, thus this so-called variety from the very beginning was really composed of four clonal varieties indiscriminately mixed together. It is therefore not surprising that many writers have commented upon the different types of Placentia. It may well be assumed that one of the four original seedlings is superior to the rest in productivity or blight resistance. There are, no doubt, many heterogeneous Placentia groves from which scions are now being taken, which should be carefully gone over during harvest to eliminate the least desirable types. The two outstanding types most commonly found in the Placentia mixture, are a roundish type which produces a large percentage of rather rough nuts, and a more oval type which is composed almost exclusively of very smooth nuts. The former type is shown in figure 5, and is probably more commonly found than the latter type.

The Placentia variety has been grown with marked success throughout the coastal sections of southern California, and some of the best grafted trees in the inland valleys of the south are of this variety. The placentia has not become popular with the walnut growers of central or northern California, because it seems to lose some of its tendency for precocity and heavy production, and is further hampered by its production of dark kernels in those districts.

Eureka.[10]—This variety was originally selected because of its supposed resistance to walnut blight, the heavy production of the parent tree, and the exceedingly high quality of the nut. The supposed resistance to blight has not been substantiated.

The Eureka is not usually so readily propagated upon the black walnut root as some of the Santa Barbara soft-shell varieties. The trees are vigorous growers, although the growth may not be so great

[10] The parent tree of the original Eureka tree was a Persian or Kaghazi type of walnut which grew on the old Meek estate near Hayward, California. The seedling which developed into the original tree was located in the dooryard of a ranch about a mile south of Fullerton. Here it grew to be a mature tree, but died of a root disease during the summer of 1923.

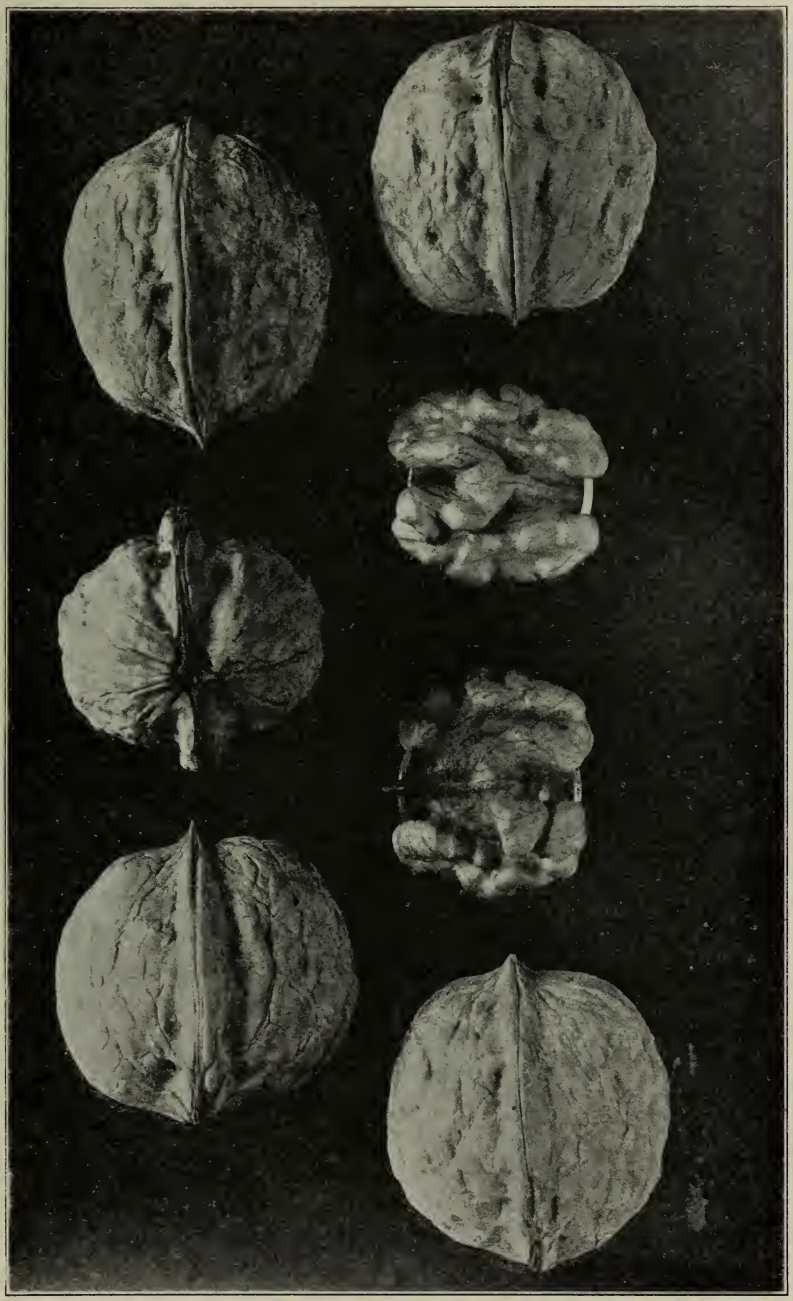


Fig. 7.—Ehrhardt (natural size).

as that of the Placentias in the same orchard. The Eureka is later in reaching an age of profitable bearing than the Santa Barbara soft-shell varieties in southern California.

The tree blooms much later than most other varieties and often escapes injury to the flowers by late spring frosts. Its harvest season is fully three weeks later than that of seedling nuts, or of the Placentia. This is a distinct disadvantage in marketing the crop in the eastern cities in time for the holiday trade.

The Eureka variety has suffered a great deal from injury caused by being frosted during the early fall. This may be due to a characteristic of late ripening, or to the possibility that the Eureka has been planted in places most subject to frost because of its late blooming habit.

The Eureka nut is easily distinguished from any other variety grown in southern California by its pronounced elongation, rather straight parallel sides, slightly rounding to square ends, with the apex usually broader and more nearly square than the base (fig. 6). The color of its shell is a bright straw, of a lighter, more attractive shade than the typical soft-shell nuts. The extra heavy shell and the exceptionally and completely firm "seal" of the nut, make it a model nut for good keeping qualities, and for withstanding commercial handling. A well-grown Eureka nut is filled to its full capacity with a light, cream-colored, plump, waxy kernel, with rather deep convolutions, possessing the very best of eating qualities. The Eureka is richer and freer from astringency than the soft-shell varieties.

The kernel of the Eureka walnut will not usually fill out perfectly on all four quarters. For this reason the variety has been very disappointing in southern and some of the central California districts.

Ehrhardt.[11]—The location of the original seedling tree from which this variety was propagated is apparently unknown.

The Ehrhardt walnut is of the Santa Barbara soft-shell type, closely resembling in some ways the Placentia. It is somewhat rougher, slightly larger, and better sealed. The kernel gives the impression of being more plump than that of the Placentia, because its convolutions are very shallow.

The variety is readily propagated, making a tree of medium vigor, which bears at an early age. It will probably succeed where the Santa Barbara soft-shell type succeeds.

[11] For a detailed description and history of this variety the reader is referred to Batchelor, L. D. Walnut Culture in California. California Agr. Exp. Sta. Bul. 332:1–80. 1921.

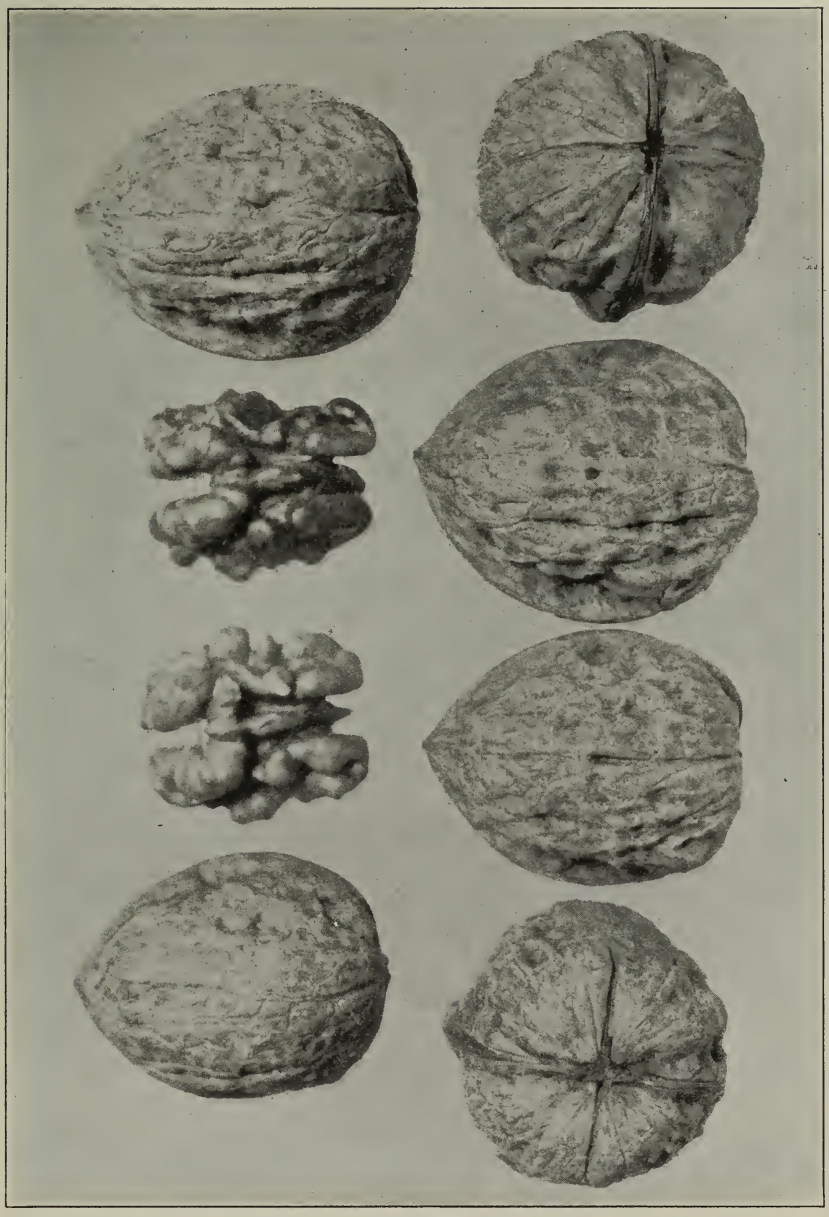


Fig. 8.—Payne (natural size).

Its tendency to produce very heavy crops of high-grade nuts, apparently out-yielding the Placentia, makes this variety worthy of extended commercial planting, especially in the coastal districts of southern California. Several trees top-grafted to Ehrhardt have shown remarkable production in Santa Clara County.

The nuts (fig. 7) are well considered by the wholesale trade. One of the distinct advantages of this variety is the fact that it so closely resembles the Placentia that it is sold with the latter variety in the budded grade. This simple wholesale disposal of a relatively new variety is a decided asset if it is to be planted in sections already largely devoted to the Placentia.

Payne.—(Synonyms: Losee Payne, Cluster Mayette, Losee.) The parent seedling tree of this variety was discovered by G. P. Payne in his grove, near Campbell, California, in 1898. The variety has not been widely planted and only in recent years has it been propagated in any quantity. This variety somewhat resembles the Franquette regarding shape and eating qualities. Its precocity in reaching heavy production is probably the chief characteristic which has brought it into prominence during the past few years. In this respect it exceeds any other variety produced in the state. The Payne is notoriously subject to blight.

The Payne tree makes a rather slow growth, possibly because of its very heavy production as a young tree. The nuts are borne rather prominently on the outside of the trees and are thus subject to severe sunburning in the inland valleys during years of abnormally high temperatures.

The nut (fig. 8) is oblong, rather pointed at the apex; shell of medium thickness, somewhat pitted, and well sealed; kernel full, with moderate convolutions, and of exceptionally mild flavor. With the heavy production of the oldest trees growing at present, there seems to be a reduction in the size of the nut, making a high percentage of small sizes. This nut has been sold in the Fancy grade, under its varietal name. It is well liked by the wholesale trade and usually brings as much or more than the Budded grade, on account of its especially fine quality.

The greatest popularity of this variety is found in the Stockton, San Jose, and Concord districts. It might be suitable to interplant in a Franquette grove and for such use it may be of great value. Thus during the first ten or twelve years of the growth of the orchard, the total production would be more than doubled. After this period the Franquette trees will require all of the space. In the districts of

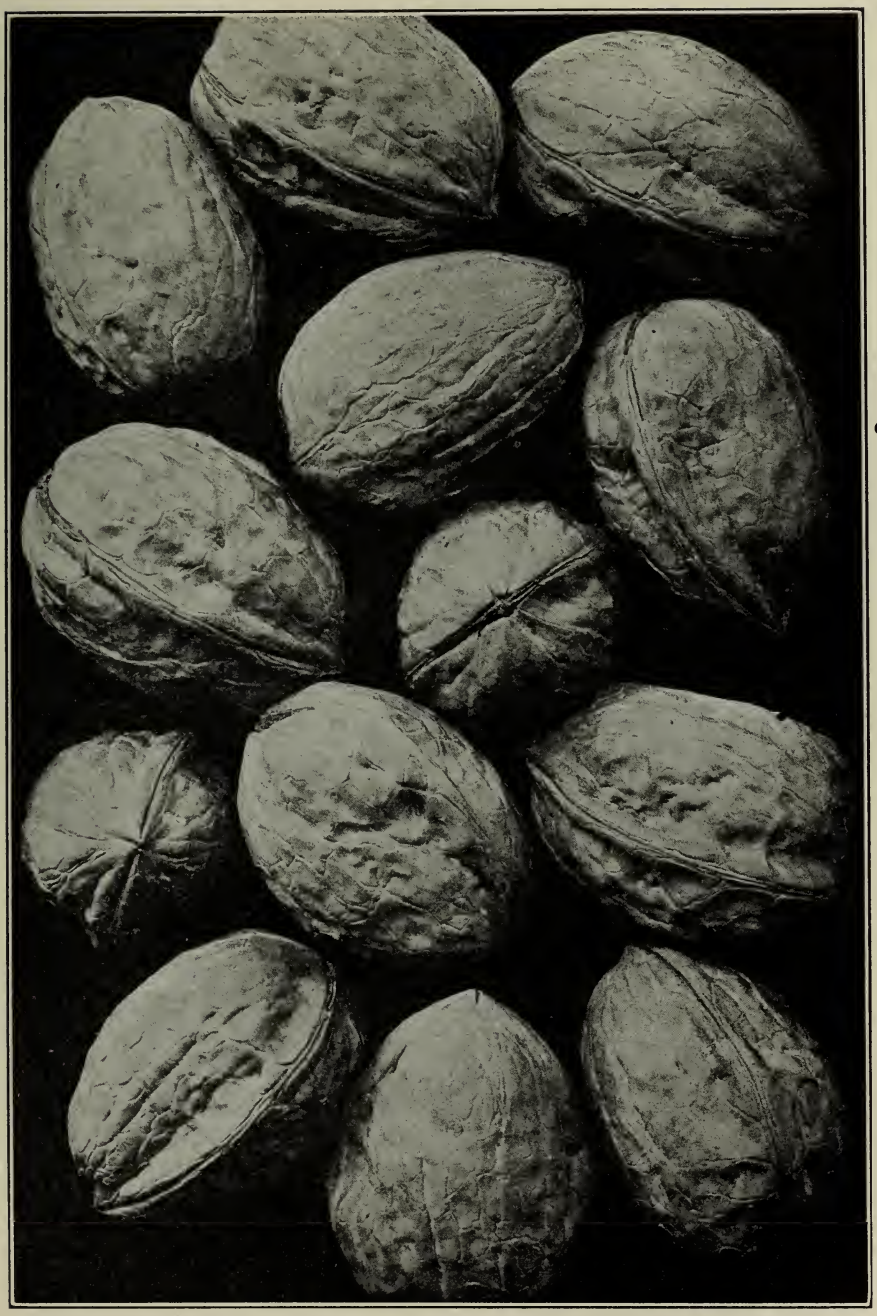


Fig. 9.—Franquette (natural size). (From Bulletin 231).

the coastal counties where the blight is most regularly severe and prevalent, the Payne variety certainly cannot be recommended for permanent trees.

Concord.—The Concord is one of the varieties most extensively planted in portions of California, especially in Contra Costa and Napa counties. In these districts it has proved to be a vigorous, thrifty tree, and an annual producer of medium-sized crops. The trees are fairly precocious. The nuts are elongated and somewhat pointed at the apex; the shell is rather smooth; the nuts are poorly sealed, the kernel fairly plump, with medium to deep convolutions, only medium light-colored and of good quality. This variety is not so well received by the wholesale trade as the Placentia, Ehrhardt, Franquette, or Payne. It is doubtful if it should be planted where the above-mentioned varieties will succeed. In southern California the Concord does not yield so well as the soft-shell varieties.

Franquette.—This well-known commercial variety of France was introduced into that country in the section around Vinay, Isère, in 1810[12] by a man named Franquet. The original source of the variety is not known. Felix Gillet introduced it into California in 1871. The first noteworthy commercial planting of this variety in this state is the Vrcoman grove at Santa Rosa. In more recent years very successful groves of Franquettes have been developed in Santa Clara, Napa, and San Joaquin counties from scion wood originating in the Vrooman grove. Plantings in Oregon which trace their origin directly to the Vrooman grove have been a notable success.

There are many so-called Franquette groves which do not trace back to the original introduction of this variety, and in reality they are not the true Franquette. Some of these misnamed collections have been the means of reflecting great discredit on this very meritorious variety. In other instances the misnamed collections are clearly some of the other varieties from France which have considerable merit, but it is doubtful whether they are as well adapted to central and northern California conditions as the true Franquette. In planting this variety in the future we believe great pains should be taken to obtain the pure strain from well-known high-producing trees. The Franquette should not be looked upon in any sense as a type; on the contrary is a pure clonal variety of long standing, and can be perpetuated thus if care in scion selection is exercised.

[12] Treyve, L. Quelle variétés de noix cultiver en France. Vie a la Campagne 22(260):52. 1925.

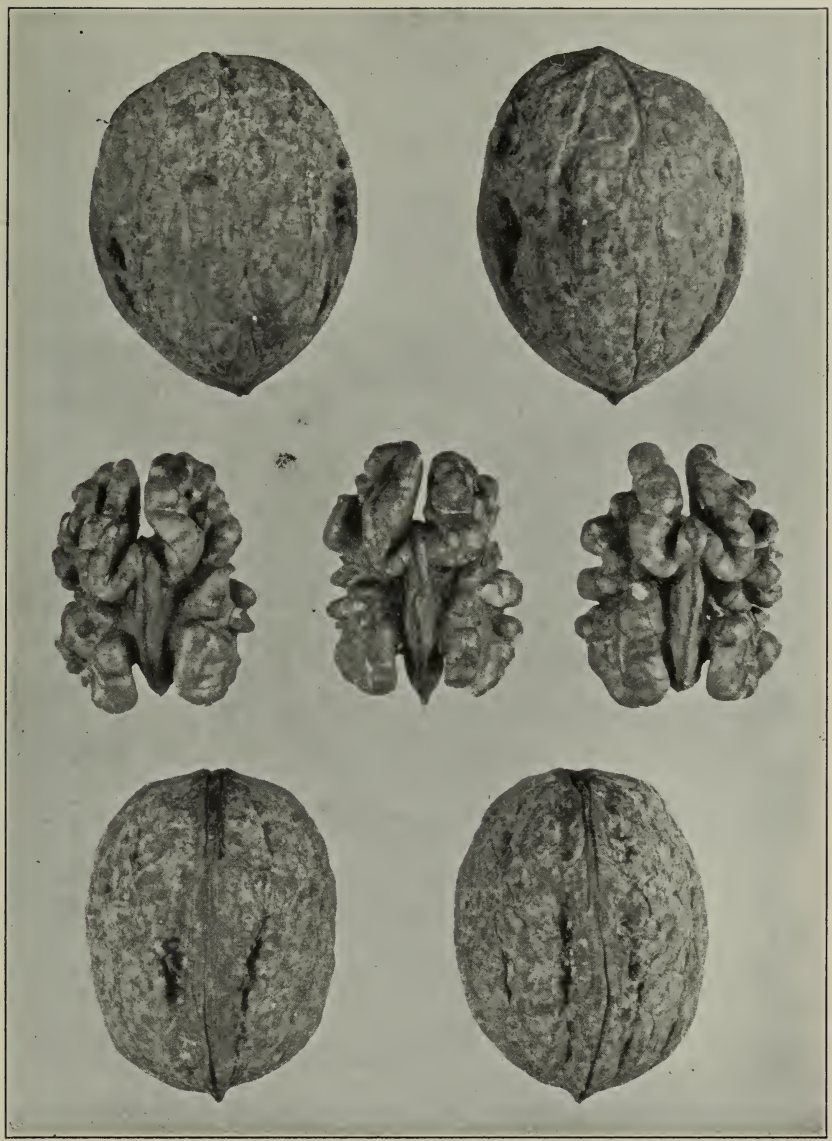


Fig. 10.—Grove (natural size).

This variety has been tested longer in central California than any other. It has many adherents in these sections because of its regular crops of moderate size and of excellent quality. It is less liable to produce dark kernels, due to high maximum temperatures, than the Santa Barbara soft-shell varieties. In southern California, the Franquette has not proved commercially successful.

The Franquette is only a medium producer during the first ten years of its growth. It blooms very late, and the harvest season is too late for the most advantageous disposal of the crop for the eastern holiday trade. Owing to its late blooming it usually escapes injury by late spring frosts.

The nut (fig. 9) is large, elongated, pointed, fairly smooth, and of a lighter, clearer and more attractive color than the soft-shell types. The shell is thin, but well sealed, and fairly well filled with a very light-colored, moderately plump kernel. The eating qualities of the Franquette are unsurpassed by any variety grown in California. The high quality of this nut makes it sell for a higher price than most other varieties grown in the state.

Grove.—The Grove walnut has attracted attention throughout the neighborhood of the original tree, at Lawrence, California, where it is known locally by the name of its original owner, the late Mr. L. E. Grove. The original tree is a chance seedling, growing in the door-yard, and it was one year old when Mr. Grove came into possession of the place. Nothing has been learned about the parentage of this tree. It has an upright habit of growth with a striking amount of fruiting wood for the size of the tree.

The tree blooms late, probably a little later than the Payne, while the nuts mature from October 1 to 15. The foliage is large and dense and the nuts have not been subject to sunburn. The tree and nut characteristics suggest that this tree may have some Franquette heritage.

The nut (fig. 10) is of medium size, oval, somewhat pointed on the blossom end, exceptionally well sealed, with a heavy shell. The kernel is plump, with rather deep convolutions, and lighter colored than the Santa Barbara soft-shell type of nuts.

The percentage of kernel in several random samples produced during the past three years has varied from 50 to 52 per cent. From 35 to 40 nuts of these samples weighed a pound.

The most valuable characteristics of this variety are its precocity and heavy bearing, and the fine eating quality of its nuts, which are of a desirable commercial type. The Grove is worthy of commercial trial in central California.

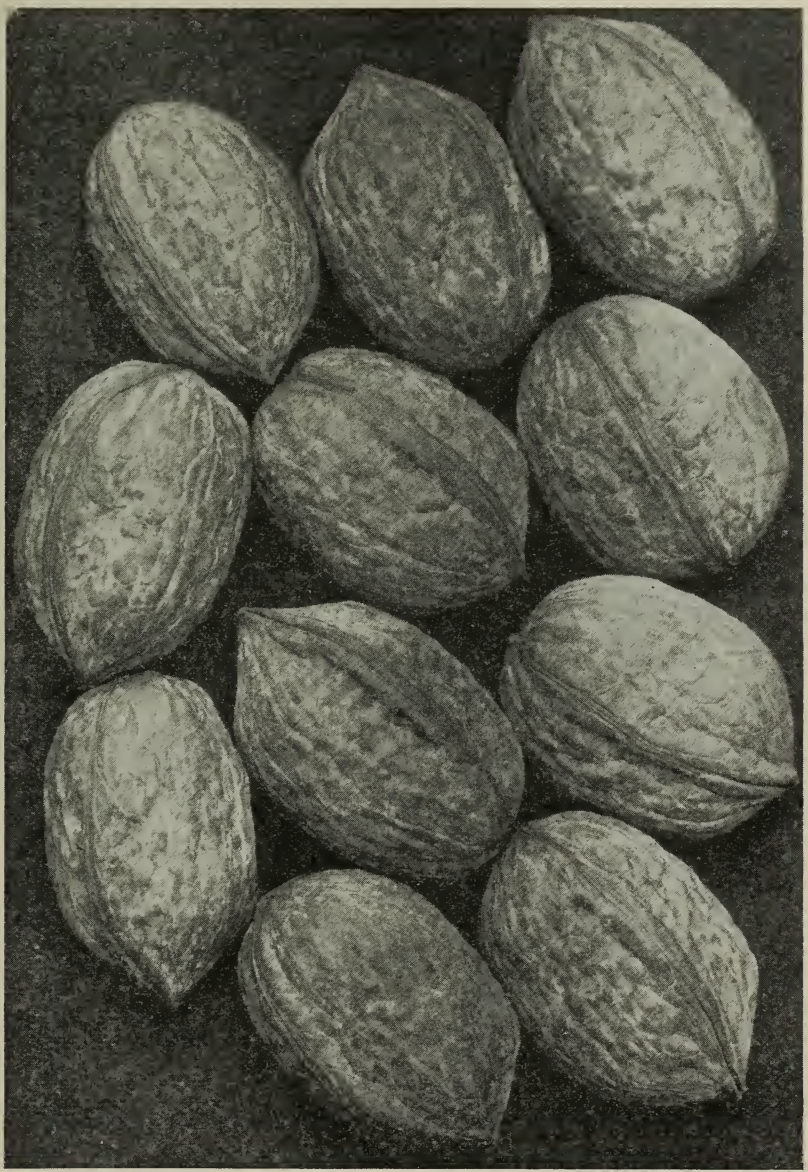


Fig. 11.—Blackmer (natural size).

Wasson.—The original Wasson tree is located in a grove on the highway between Ventura and Santa Paula about one mile east of the Saticoy road, on the property of Lee Hawley. The tree is now 45 years old, 35 feet high, and has a 60-foot spread.

The orchard in which it is located was planted in 1885 from seed obtained from the original Sexton orchard near Santa Barbara.

The Wasson is large and rather rough with the suture coming up full width to the stem end on one side and suddenly flattening out for a quarter of an inch or so on the other side. The nut is well sealed and the shell solid and hard. It will stand much more abuse in handling than the Placentia. The tree is precocious and bears relatively large crops.

The Wasson is apparently adapted to the same sections as the Placentia.

Pride of Ventura.—The Pride of Ventura is a selected type of Santa Barbara soft-shell seedling. The original tree is located in Ventura County near Ventura.

It is precocious and bears heavily. The nuts are large, fairly smooth, and the shell is heavy and well sealed.

The very limited plantings in Ventura County indicate its superiority for that particular section. It should be considered an untried variety for the interior sections.

Blackmer.—This variety is also known as the *Mautner, Westfall, Westphal, Meridian, Leib and Leib Special, Vaughn's Pride,* and *Money Maker.* The original tree is still alive and is located two miles south of Meridian on the east bank of the Sacramento River.

The nut (fig. 11) is large, long, and pointed. The shell is very light colored and bleaches easily. It has a heavy shell and is well sealed. The kernels are large, plump, good quality, and light colored. It is marketed as a fancy variety.

The tree comes into bearing fairly early and bears heavy crops. It is a vigorous grower and consequently must be planted at greater distances than some of the slower-growing varieties.

The Blackmer blooms comparatively early and may often be damaged by late spring frosts. The nuts ripen early in the fall, which is a decided asset.

The Blackmer has been thoroughly tested in central California in recent years. In southern California it should be considered essentially an untried variety.

ROOTSTOCKS

Northern California Black Walnuts.—The choice of rootstocks for the walnut has narrowed down during the past twenty years to a predominating preference for the northern California black walnut (*Juglans californica* var. *hindsii*). The seed is shipped commercially by several agencies from central California for this purpose. Groups of dooryard and border trees usually furnish this seed. Some nurserymen in southern California have located and use seed from particularly vigorous black walnuts of this species, which have been planted locally. The seedlings from a group of such trees vary considerably, and in some instances certain trees are especially valued because of their tendency to produce uniform and vigorous seedlings.

This variety of the species is resistant to some degree to the oak root fungus (*Armillaria mellea*); this, in fact, is probably its most valuable characteristic. Were it not for the presence of oak root fungus in some of the walnut-growing districts, the black walnut rootstock would not be of any particular advantage in comparison with the ordinary seedling rootstock of Persian walnut (*Juglans regia*). The hard-shell type of this latter species, which was heretofore common in California, makes a large vigorous tree and has much to commend it where the oak root fungus does not occur.

One of the greatest disadvantages in using the northern California black walnut as a rootstock is its susceptibility to crown rot (*Phytophthora*). This disease has become increasingly troublesome during the past decade. The matter is further complicated by the fact that the northern black walnut (*Juglans californica* var. *hindsii*) is merely a variety of and is often confused with the southern California black walnut (*J. californica*)[13] and the latter is especially susceptible to the crown rot. Plantings of both varieties occur in southern as well as northern California. Therefore there has been much confusion in the past in attempting to obtain a pure strain of the northern variety for rootstock purposes. The fact that seed came from northern California has not always been an assurance that the northern species was obtained.

Southern California Black Walnut.—Large collections of California black walnuts may show trees typical of the northern variety and other trees typical of the southern form with many specimen trees representing various intermediate types. This very heterogeneous

[13] Jepson, Willis Linn. The silva of California. Univ. California Memoirs 2:195. 1910.

species may, therefore, be considered to contain one type (*Juglans californica* var. *hindsii*) which is distinctly arboreous in form, with a tall trunk and large fruit (1¼ to 2 inches in diameter). This type makes a good graft union with most of the varieties of the Persian walnut. The other type (*J. californica*) is more variable, generally branches near the ground, and assumes a more shrub-like habit of growth. It does not form a smooth graft union with the Persian walnut and has the added disadvantage of being very subject to crown rot. The graft union is characterized by an enlargement of the black root just below the graft union to two or three times the size of the Persian walnut directly above the graft union. This condition of growth produces a partially girdled condition and often is associated with a dwarfed condition of the trees, together with especially large crops in proportion to the size of the tree. A tendency to sucker profusely at the crown is another undesirable characteristic of the southern California black walnut.

Hybrid Rootstocks.—The Paradox-hybrid rootstock, which is a cross between the English and any of the black walnuts, makes a remarkably rapid growing tree. Mature trees may have a spread of 60 to 90 feet. The vigor of this first-generation hybrid has been mainly responsible for its popularity among some planters. Such trees in the past have not been produced in any large quantity and due to the difficulties in propagating hybrids it seems probable that their use in the future will be only in a restricted way. The increased vigor of the first-generation hybrid is not carried on to following generations; in fact, the first-generation hybrid trees are usually nearly barren, and their seedlings show many types of growth and vigor, making undesirable rootstocks.

The Royal-hybrid walnut is a cross between the eastern black walnut and the California black walnut. It is thought by some that the second-generation Royal-hybrid is equal or even superior to the northern black walnut as a rootstock. There may be hybrid strains which justify this confidence, but it cannot be said that such superiority is universal. Seedlings from some of the Royal-hybrid trees produce uniformly vigorous trees, while those from others are variable and lack vigor. Probably the pollinating parent has much to do with this lack of consistency.

Persian Walnut Seedlings.—The variability of the California black walnut, and thus the many disappointing results of its use as a rootstock, as heretofore discussed, has been the means of turning the attention of the industry to the use of the seedlings of the Persian

walnut (*Juglans regia*) as a rootstock. If the seedlings are grown from especially vigorous trees, such as the hard-shell variety, we know of no disadvantage in using them wherever the oak root fungus is not a consideration. They have the advantage of making a smooth graft union free from any girdling effect, and are also apparently much more resistant, under orchard conditions, to crown rot than the black root. This latter characteristic has been its principal reason for popularity in several of the districts of southern California where the root-rot has become increasingly troublesome during the past decade.

It was thought at one time that possibly the black walnuts of the several species were more resistant to unfavorable soil conditions than the Persian walnut. In the case of alkali soils the blacks have been recommended for use. During the past few years many walnut groves have been injured by using irrigation water containing harmful amounts of alkali. In observing many such groves it is apparent that the black walnut does not show any greater resistance to injury than the seedling Persian trees on their own roots. Increasing use of the Persian seedlings for rootstock purposes seems entirely justified.

METHODS OF PROPAGATION[14]

The English walnut is usually grafted on to the black walnut root during the early spring, using a whip graft. It can be budded[15] however, and some nurserymen prefer this method.

Grafting.—One year from the time of planting the nuts in the nursery the seedlings should be ready for grafting. By this time they should have attained a diameter of one inch or more at the surface of the ground. The surface soil is hoed away from the crown of the trees to a depth of 2 or 3 inches and the scion is inserted in the stock just below the surface of the ground. After the scion is tied and thoroughly waxed, the soil is hoed back over the crown of the tree covering scion and all to a depth of one or two inches. Well-pulverized soil is essential in covering up the grafted trees for the presence of

[14] Stahl, J. L. Propagation of deciduous fruits. California Agr. Exp. Sta. Cir. 294:1–24. 1925.

[15] The question is often asked: "What is a budded walnut?" The grade of nuts sold under the name "budded" has no doubt prompted this question in many instances. A budded nut is any one of the varieties which will grade according to the standard of perfection set by the Placentia. The tree which bears such a nut has been produced by budding or grafting a bud or scion of the variety in question on a seedling rootstock. If budded, the work is usually done in August, using a patch or a shield bud from the current season's growth.

clods is likely to result in the scions being loosened or knocked out of the stock.

The grafted trees are grown one year in the nursery and trained to a whip-like growth free from lateral branches. It is necessary to tie each tree to a stake. Stakes 1 in. by 2 in. by 8 feet long make satisfactory supports. Considerable pains is necessary throughout the growing season to tie up the rapid growing trees periodically so they will continue to grow straight.

Budding.—When walnuts are propagated by budding, the nuts are given an early start and the seedlings kept rapidly growing until August. At this season they are large enough to receive a bud near the surface of the ground. Patch budding is the method most commonly followed, although a shield bud may be successfully used if the chip of wood is carefully removed from the bud. It is essential to have the bud ripened by removing the leaf, leaving the petiole attached to the base of the bud for a period of about 10 days before the buds are cut. After the buds are inserted in the stock they are firmly tied in place by means of waxed cloth. This must be loosened at about ten-day intervals until the buds have become attached to the stock. The buds are usually allowed to remain dormant until the following spring.

STARTING THE YOUNG ORCHARD

Requirements for Good Nursery Trees.—Grafted trees sell according to size, a premium being placed upon the larger trees. The price of well-grown walnut trees varies from $1.00 to $2.00. A medium-sized tree (8 to 10 feet) may be preferable to either an extremely large, or a small tree. A very large tree may be injured considerably in digging from the nursery, while a small one may be stunted, with a poor root system, and never make a first-class orchard tree. Although a considerable premium is usually paid for the largest trees, it is doubtful if they are actually worth any more than those of medium size.

Planning the arrangement of the Orchard.—From 12 to 27 walnut trees to the acre are found in the mature orchards. General observation and the opinions of many walnut growers agree that the trees have in the past, been planted too close in walnut groves in general.

Orchards planted with the trees 60 feet apart each way are among the most productive in the state. With this spacing the individual trees have room to develop fully. A large proportion of the nuts are produced on the side branches, and the trees maintain a healthy vigorous growth of new fruiting wood for many years.

Fig. 12.—The trees in this orchard were planted too close, being spaced 40 feet. They are producing walnuts only in the tops and will soon have to be thinned in order to obtain a satisfactory yield per acre. (From Bulletin 332.)

Fig. 13.—An old seedling grove thinned out by removing every other diagonal row.

In the close plantings, where the trees are only 40 to 50 feet apart, the side branches are shaded most of the day, the fruit spurs on the lower branches soon die, and the crop is borne mainly in the tops of the trees. A closely planted grove is illustrated by figure 12. Such orchards have not maintained their productivity so well as those planted less densely. Plantings where the trees are 40 or 45 feet apart can be thinned out by removing every other tree in each row so that the trees alternate, or stand opposite a space in the adjacent rows. This is the same as removing every other diagonal row. The remaining trees will then stand approximately 57 or 63 feet apart respectively in the rows, running diagonally across the orchard. See figure 13.

One of the most favored systems at present is to plant the trees 30 feet apart in rows which are 60 feet apart. The trees may be all of one variety, or of two, planted alternately. With the latter method, there is the advantage of a choice between two varieties when the time arrives for removing half of the trees. Such plantings are usually thinned out when the trees are from 10 to 14 years old, the time varying according to the variety, soil, water and climatic conditions. They should not be left until they crowd badly. If this method is properly carried out, nearly twice the tonnage may be expected during the first 10 or 14 years as where only the permanent trees are planted. At the same time, there is practically as much room for intercrops such as beans, during the early life of the orchard as if only 12 trees had been planted to the acre. The extra expense of buying and planting filler trees may be paid for by part of one year's crop, while all other extra expense due to the filler trees, such as pruning, extra water, etc., is of minor importance.

Care of Trees Before Planting.—If the trees are received from the nursery before the ground is ready for planting, they should be unpacked and heeled in where they will be shaded. The soil around the roots should be thoroughly watered after they are heeled in. If it is more practical, the trees may be held for a time under a shed with the roots packed in damp sawdust or shavings.

Planting Nursery Trees.—Walnut trees should be planted during January or February so that the soil may be thoroughly settled around the roots and growth start with the beginning of the normal growing season, which is usually March in southern California. Holes should be dug deep enough to allow room for the full length of the tap root, which may be from 18 to 30 inches. The lateral roots may be 6 or 8 inches long, and the hole should be wide enough to accommodate them.

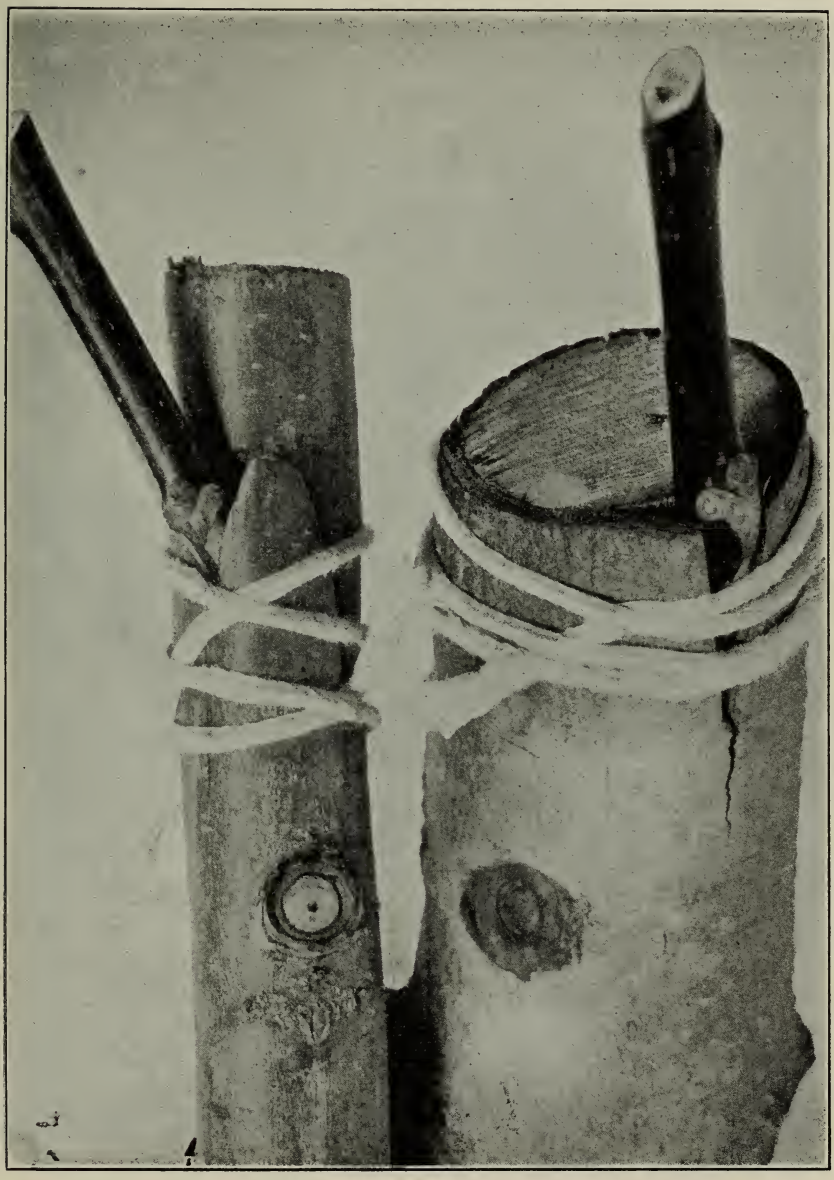


Fig. 14.—Example of side and bark graft scions tied in place ready for waxing.

In filling in the soil around the roots, it is advisable to use the top soil, tamping it thoroughly without bruising the roots. A better stand of trees may be expected, and a prompter growth in the spring, if the young trees are thoroughly irrigated as soon as they are planted. This can be accomplished by running a single furrow along the row and cutting the water in at the basin left around each tree when it was planted. Irrigation at this time may not be essential from the point of view of available soil moisture but it will be well worth the extra care, as a means of thoroughly settling the soil around the roots to prevent their drying out. A few light rains should not mislead the planter and cause him to omit this first irrigation at planting.

Planting the Orchard with Black Walnut Trees and Top-Grafting.—In several parts of central California, especially in Contra Costa County, the planting of nursery-grown walnut trees has frequently been followed by a rather poor stand, and a slow growth of the surviving trees during the first 2 or 3 years. Walnuts are usually grown in this district without irrigation water and it seems probable that the poor results with nursery trees is directly traceable to the failure to water the trees at the time they are planted. In any event the past experiences have led the present planters to favor the planting of the black walnuts in the field and top-grafting the resulting trees when they are from 2 to 5 years old.

Two or three walnuts are planted in each place where a tree is to grow. During the early summer the smallest trees from each group are pulled out, leaving the most vigorous one.

In the Stockton and Linden districts one-year-old black walnut trees are planted in orchard form, rather than nuts. With good soil conditions and water available, black walnut trees or nursery-grafted trees should be readily transplanted with nearly all making a good growth the first year.

Various methods of top-grafting are recommended by the advocates of this general method of starting a walnut orchard. The two-year-old trees may be grafted in the main limbs near the trunk by means of a side-graft. If the trees are 3 to 5 years old they may be top-grafted by means of a bark graft or a cleft graft. Figures 14 and 15 show the detail method of making side, bark, and cleft grafts. The particular type of graft best suited to this method of propagation depends largely on the size of the stock and the scion. The side graft is preferable on small branches, and the bark-graft or the cleft-graft method is the most usable on limbs 3 to 6 inches in diameter.

Whatever method of grafting is practiced, one of the most important details of this operation is in regard to waxing. All cut portions of the stock and scion should be covered with wax as soon as the scions have been tied in place. A hot wax made from the following formula is commonly used: resin 4 parts, beeswax 1 part, linseed oil 1 part.

Fig. 15.—Cleft graft ready to wax.

There are also prepared waxes on the market which are not so apt to crack with weathering as wax made according to the above formula. Bi-weekly inspection and rewaxing to keep all the cracks in the wax covered over is essential to success. Water-emulsified asphalt compounds make a satisfactory grafting wax. These compounds are used cold.

Patch-budding is another method sometimes followed in top-working young black walnut trees. Two-year-old trees with one-year-old frame work branches 5/8 to 7/8 of an inch in diameter are an ideal size to top-work by patch budding. The buds are usually placed in the branches, about 6 to 12 inches from the main trunk. With the

buds thus placed the eventual orchard tree has a trunk and the base of the scaffold limbs of the black walnut as shown in figure 16. The black walnut wood is stronger than the English walnut—an advantage in favor of such top-worked trees.

Fig. 16.—Black walnut top-worked in limbs.

Whatever method of top-grafting or budding is used, considerable care and expense will be necessary in bracing and tying the new top. Without adequate bracing the scions may be blown out of the stock

before they reach the end of the first year's growth. It is not advisable to let the growth go beyond 12 or 15 inches before the supports are put in place and the scions receive their initial tying. Periodically through the first year, the suckers should be removed from the trunk and framework branches and the rapid scion growth retied as the growth proceeds. It may be necessary to go over the planting four or five times the first summer if the trees are large when top-worked and the growth of the new top is rapid. Figure 17 shows the method of bracing the top of grafted trees during the first year.

Top-grafting walnuts is an art which requires considerable skill. The follow-up care of the scions the first year requires much pains and persistence. This method of establishing an orchard is less practicable in the hands of most farmers than planting nursery-grown trees.

Training Young Trees.—If walnut trees are allowed to grow without any pruning they will usually take the form of a medium tall, upright, pyramidal tree, with a pronounced central leader. At the time of planting the trees are usually headed back 5 to 6 feet from the ground, and the upper lateral bud will frequently make an upright limb which will take the place of the removed top and continue the leader form of tree. If this central branch is later pruned off, however, the lower lateral branches will form a more open vase-shaped tree. These lower lateral branches thus once started, intercept the sap flow to the leader and another leader seldom becomes established. Figure 18 shows an eight-year-old tree growing as a leader type.

Both the central leader and the open vase types of trees have their advocates. The advantage of the leader type of tree is primarily in the greater strength of the framework, there being many more lateral limbs distributed along a greater space on the main trunk than with the vase-shaped type, and thus less likelihood of breaking. In the case of the vase-shaped type the few branches originate at nearly the same point on the main trunk and this centralizes the strain of supporting the crop. In the case of the vase-shaped trees, it is not unusual for one-quarter or one-half of the tree to break off and, in extreme cases, there may be a split down the middle and the tree be entirely destroyed.

Figure 19 shows an old walnut tree which was trained to the open vase-shape. It may be necessary to have from 15 to 20 per cent of the trees in such groves braced by the time they reach an age of profitable bearing. The example here illustrated may be considered extreme because the lateral limbs originate at so nearly the same point.

Fig. 17.—Supports in place ready to tie growing scions on top-grafted trees during the first year.

After one has decided upon the type or ideal toward which the young trees are to be trained, the pruning operations should be consistent in following this initial decision. In training the young walnut tree, very little pruning is necessary. Walnut trees as they are received from the nursery are usually one-year-old whips. If vigorous 8 to 12-foot trees are planted they are usually cut back to within 5 or 6 feet of the ground.

Fig. 18.—Central leader type of walnut tree. This type has a strong framework of branches and plenty of fruiting wood. (From Bulletin 332.)

Trees thus planted will frequently start to grow first from the lower buds within 12 to 24 inches of the ground, or will send out shoots along their entire length. If the lower lateral buds have made a growth of 4 to 6 inches it is advisable to pinch off the growing tips, which will have the effect of forcing the growth into the upper shoots which

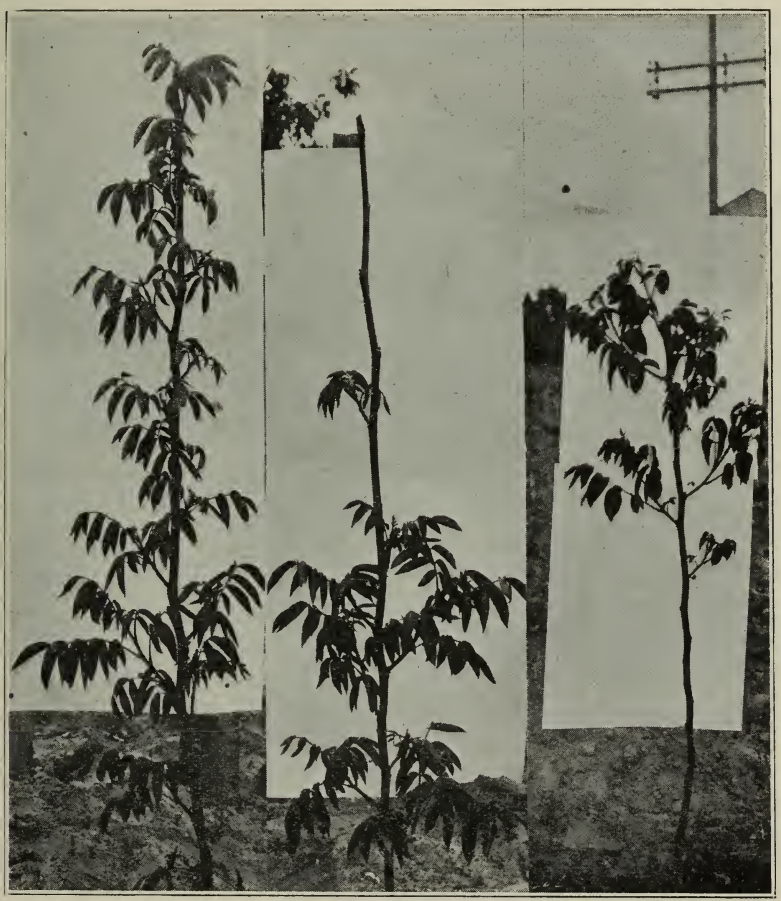
are to form the eventual framework of the tree, while the growth of the lower, pinched shoots is restricted. The smaller lower shoots thus produce shade and nourishment for the trunk. This growth might be rubbed off by going over the trees frequently during the early summer, keeping all buds off which occur within 4 or 5 feet from the ground, according to the form of tree to be grown, and their height at planting. However, the former method is preferable. If the lower dormant buds are rubbed off at planting, more of the growth will take place in the upper buds and require less attention, compared with

Fig. 19.—Old walnut tree trained to open-vase shape.

planting them without this precaution. If, on the contrary, the lower buds are allowed to grow, the buds on the upper 24 inches of the tree may remain dormant; in fact, in many instances the upper portion of the tree dies back 12 to 24 inches following the vigorous growth of the lower shoots. With the lower buds suppressed, however, the upper buds are forced into growth and the framework of the tree is started in the upper 24 inches of the trunk. This is illustrated by figure 20.

A few planters advocate cutting the young tree back to within 12 to 16 inches of the ground. This method forces into growth the latent buds near the ground; one of these is selected to make the tree, and all others are rubbed off. The selected shoot must be staked and tied to a 2 in. by 2 in. stake, 5 to 6 ft. tall, otherwise the supple growth will be whipped around and bent over by the winds. It is claimed that

this method gives a better stand of trees, and less liability of sunburn injury on the trunk. The tops thus cut back are relatively surer to balance up with the root systems injured by digging. It may be well to doubt if the extra expense in staking and in the care necessary to grow a tree in this manner will repay for the assurance of the growth



A *B* *C*

Fig. 20.—Walnut trees when planted are usually cut back to within 5 or 6 feet of the ground. (From Bulletin 332.)

A, If they are not trained they will frequently send out shoots along their entire length during the early summer.

B, Frequently if the lower buds within two feet of the ground are allowed to grow, the upper 24 inches of the tree may remain dormant.

C, If the lower buds are suppressed the upper ones are forced into growth and the framework of the tree is started in the upper 24 inches of the trunk.

of a larger percentage of the transplanted trees. Good, plump nursery trees, if handled properly, should transplant very readily and make nearly a 100 per cent stand of trees without resorting to this severe cutting. If they are thoroughly whitewashed, or use is made of tree protectors, sunburning need not be feared. It may be advisable, however, if one is using inferior trees, planting very late in the spring or if using trees which have dried out in transit, to cut them back within 16 inches of the ground.

Whether the ideal selected is the leader type or the open-vase shape, it is desirable to select the lateral branches for the framework of the trees spaced as far apart as practicable when the young trees are pruned at the end of the first year's growth.

With the vase type this perpendicular spacing throughout 18 to 24 inches will give greater strength to the framework than grouping the branches at more nearly one point of origin. The lateral branches to be left for the framework of the tree may be 3 to 5 in number, as evenly spaced as possible as they radiate outward from the trunk. The upper or second bud from the top of the tree after being cut back will usually produce a branch which grows in a nearly upright position; this, of course, should be pinched back during the early summer or cut out during the dormant season, in forming the framework of an open vase-shaped tree.

In the case of the leader type it is essential to space the laterals far apart and not leave too many; otherwise the leader, or central shaft will be choked out, as illustrated by figure 22. Only two or three of the laterals should be left in addition to the central leader at the end of the first year, as other lateral branches will grow out during the following years from the central leader; thus the shape of the tree is formed during the first two or three years' growth. The branches which are left on the tree are not cut back in common practice and by no means should the leader be cut back.

The greatest drawback to training walnut trees to the leader type is the practical difficulty of attaining the ideal which is in mind. It is difficult to visualize the distance which must exist between the lateral branches to prevent choking out the leader. Many young trees which follow the leader type of growth during the first five to seven years of their existence, finally become a modified leader type or very nearly an open-vase type during the succeeding five years. This is usually due to misjudgment in spacing the lateral branches during the first two years growth in the orchard.

The trees that have not made a satisfactory central leader type during the first four years will very soon become an open-vase type unless precautions are taken to prevent this. The formation of a modified central leader type of tree is in this case the best alternative. This is illustrated by figure 21.

This type of tree has several large well-spaced branches, no one of which is a central leader. A tree of this type has combined some of the good points of the central leader and of the open-vase into one tree.

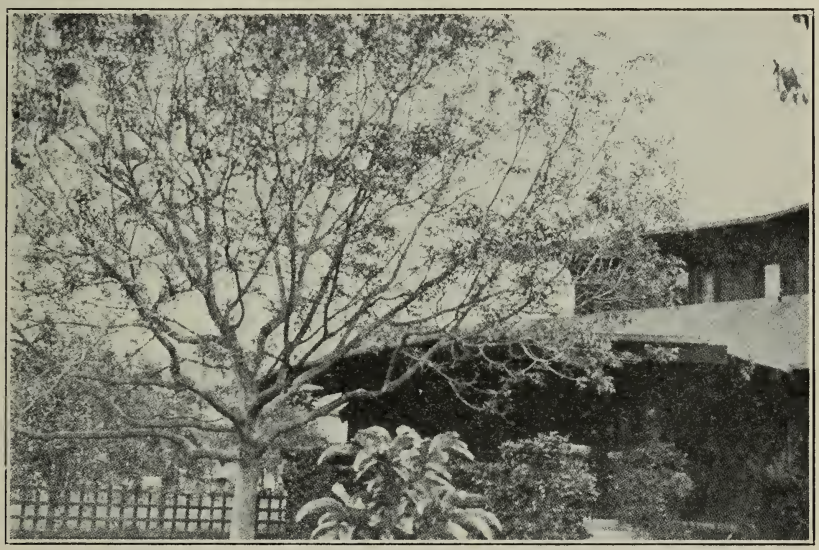


Fig. 21.—A modified central-leader type of walnut tree, combining some of the good points of both the leader and vase-shape types. (From Bulletin 332.)

The branches are spaced so that there is no crowding of one another. They are strong and seldom break as do the branches of the open-vase type of tree.

The modified central leader type of training for the young tree is to be considered second to the central leader type but much better than the open-vase type. Trees which have passed the point where it is possible to form a central leader can be shaped into a modified leader very easily.

Value of Orchards and Lands.—The valuation of walnut orchards and lands suitable for walnut production varies considerably in the different localities and even in the same districts. Such factors as

suitability of the soil, water rights, frost conditions, and proximity to transportation and civic centers are reflected in the appraised valuation of walnut properties. The value of established groves may be greatly influenced by the variety of nut, rootstocks, planting arrangement, etc. The average or the most general valuations are all that can be presented here.

Replies to questionnaires sent out by the California Walnut Growers' Association in 1919 and again in 1921, indicated that mature bearing orchards were valued at about $1,400 an acre, while the young non-bearing properties were valued at approximately $900 an acre.

TABLE 9

AVERAGE VALUATION OF WALNUT GROVES
(Including water rights)

Year	Valuation		Number of properties represented
	Bearing	Non-bearing	
1919*	$1,299	$995	922
1921†	1,477	827	231
1928¶	1,396	858	‡

* California Walnut Growers Association. The California walnut. *p. 15.* Published by Calif. Walnut Growers, Assoc., Los Angeles. 1919.

† The Walnut Protective League. Brief of facts relating to the American walnut industry. *p. 23.* Published by the Walnut Protective League, Los Angeles. 1921.

¶ Tariff Readjustment—1929. Hearings before the Committee on Ways and Means House of Representatives, Seventieth Congress, Second Session, No. 18. *p. 3554* U. S. Printing Office, Washington. Jan. 26, 1929.

‡ Includes 72.4 per cent of the bearing and 50.3 per cent of the non-bearing walnut acreage of the state of California.

The valuations set forth in table 9 are large compared to pre-war prices. When the questionnaires quoted here were answered in 1919 walnuts were selling at the highest price ever realized in the history of the industry. In 1921 when the second survey was made the price had dropped only 22 per cent, whereas many farm products had slumped to their pre-war level. If the price of walnuts in the future gradually approaches pre-war figures, walnut grove prices will probably decrease in the same proportion, but with somewhat of a lag behind the adjustments in price of the crop.

Land suitable for walnut culture, plus adequate water rights, may be purchased at from $600 to $1,000 an acre in the proved walnut-growing sections of southern California. Such land may have a rather fixed value for the production of beans, citrus fruits, or for civic purposes; thus its potential value for walnut production is only

one factor which determines its appraisement. In determining the intrinsic value of a walnut grove, the *net return per acre for a period of years* should be the main consideration.

In the central or northern portion of the state, where the walnut industry is not so extensively developed as in the south, land which is

Fig. 22—The central leader in this tree has been starved out by the lateral branches, all starting out at nearly the same place and cutting off the food supply from the central trunk. (From Bulletin 332.)

likely to prove suitable for walnut culture may be purchased for $200 to $300 an acre. This may not include a water right in any established irrigation system, but usually such lands occur in areas where good wells are known to exist.

CULTIVATION

The methods of performing the various operations of tilling the soil, such as plowing, disking, and harrowing, vary widely in different walnut groves. These different methods may give equally good results in their respective groves, when measured by profitable crop production. A practice which leaves one soil in first-class condition may be very poor practice on soil of a different type. Most walnut trees are deep-rooted and it seems apparent in many cases that the character of surface soil cultivation is of only minor importance to the welfare of the tree. There are many dooryard and roadside trees which produce heavy crops even though the soil around them may not be stirred from one year's end to another. It does not follow from this, however, that a walnut grove should not be plowed or cultivated. There are frequently many conditions surrounding roadside and dooryard trees which are favorable to the presence of an abundance of soil moisture, which cannot be duplicated under orchard conditions. Isolated trees have the advantages of better exposure to sunlight and a far greater range for root development and available soil moisture than trees planted in orchard form.

Time to Plow.—The majority of walnut groves are plowed or thoroughly disked once a year, usually in the early spring. This practice seems essential for most of the soil types found in the walnut districts of California. The relation of such plowing or disking to the penetration of the rains into the subsoils and to the application of irrigation water alone justifies the operation. Putting 6 to 10 inches of the surface soil into a friable mellow condition every year makes it practical to use deep irrigation furrows. With such deep furrows, if the grade is slight enough so they may be filled with water, deep penetration and a more complete use of the irrigation water applied will be assured.

If the land is plowed in the fall and left rough, the rains will penetrate deeper into the subsoil because of the lessened run-off. Where a winter cover crop is grown, fall plowing may be impractical because of the necessity of planting the cover crop early, either just before the harvest, or immediately after. When winter cover crops are not grown, the practice of fall plowing or disking has much to commend it. A medium to light irrigation (see "Irrigation," p. 65) may well precede the fall plowing, and the land left rough without further cultivation until the early spring.

Late spring plowing is objected to by some walnut growers; they believe the cutting of the feeder roots by such plowing to be especially harmful when the tops are just starting to grow, during late March and the month of April. The instances which are frequently cited to illustrate the poor crop conditions following late spring plowing are not readily diagnosed. It usually seems that there may be other more important factors conducive to poor crops, accompanying the late plowing. The dry soil condition which is so frequently correlated with late plowing may in itself be more truly responsible for the poor crops than the mere season of plowing. Many orchards which are plowed late have been cover-cropped or heavily covered with volunteer growth of barley, oats, native annual plants, etc. In most seasons, and in most walnut districts, the presence in late March or early April of a sown cover crop or a volunteer crop, may be taken as a safe indication that the soil moisture is largely depleted, unless the land has been thoroughly irrigated several times during the growth of the crop. The orchard in which a volunteer crop is allowed to grow is most likely to be neglected in regard to winter irrigation. Many such orchards are plowed in the spring when the annual plants have actually wilted for lack of moisture, or after recent rains have revived them by moistening the soil only to the depth of the plow furrow. The subsoil from the second to the eighth foot, in groves thus managed, may be nearly dust dry at this season when the trees are commencing to leaf out.

The amount of water required to produce a cover crop is often underestimated by the walnut grower. This is especially true when the crop is produced during the rainy season and makes a satisfactory growth without irrigation. This matter is more fully treated under the heading "Cover Cropping." In many instances when the above conditions have been noted, an examination of the subsoils has shown a dryness hardly credible. Walnut groves have been examined in which the soil below the penetration of winter rains contained only hygroscopic moisture. Walnut trees commonly reduce the soil moisture to this point during the fall months. A winter rainfall of 8 to 12 inches may not percolate below the third or fourth foot of soil if there is a cover crop or weed crop growing on the land. If the rains come in small amounts distributed over five or six months, as frequently occurs, their shallow percolation is more pronounced than when large volumes fall at a time.

It seems reasonably safe to assert that the chief factor contributing to poor crops in many late-plowed orchards is the dry soil condition

during the winter and early spring, and the late plowing which may be associated with this dryness is in no great degree responsible. Late plowing may be accompanied by careful irrigation practice and ideal soil moisture conditions, as noted later, in which case the walnut crops may not suffer.

Judging the question of late spring plowing from another angle, there are many first-class, heavy-producing orchards which are annually spring-plowed in April, when the leaves are coming out on the trees. Some of these orchards are located on the lowlands subject to winter floods, where it is necessary to cover-crop the land to prevent erosion and where this threat of flood damage is not past until April. Orchards in these districts are seldom or never plowed until late, yet many of them yield well. Such orchards are usually well irrigated during the spring or late winter months, however, either by regular irrigation methods or by the passage of flood waters over the lands.

This discussion should not be taken as an encouragement to late spring plowing, for there are points in favor of plowing early, and it seems to be the practice usually followed by successful walnut growers. It is offered mainly to encourage growers to feel that they may maintain a first-class walnut grove, even though for any reason they are obliged to plow late, provided other factors, chiefly soil-moisture conditions, are favorable to the early spring growth of the tree and nuts during late March and April when such plowing is frequently done.

Summer Cultivation.—The clean cultivation during the summer months is done primarily in relation to the irrigation practice and secondarily for the conservation of soil moisture by keeping down weed growth. Preventing weed growth is of much more importance in conserving soil moisture than the creation of a dust mulch. Weeds, like any other type of plants, require large amounts of water to enable them to grow. Deep-rooted weeds compete for soil moisture in the root zone of the walnut trees. If the soil has been cultivated sufficiently to leave it friable to a depth sufficient to facilitate irrigation, further cultivation is of doubtful value, for practically all weeds will be thus destroyed.

Subsoiling.—The practice of subsoiling walnut groves may be justified in rare cases if ever. Most of the soil types on which walnuts are being grown can readily be irrigated to a depth of 7 or 8 feet without resorting to subsoiling. The effect of subsoiling on impervious soils is likely to be only temporary. Furthermore, if it is done it will be at the expense of many of the shallow-growing lateral roots.

The benefits derived from sub-soiling under conditions where the practice was justified, has led to the wasteful use and the making of extravagant claims in favor of this rather costly practice. Land which can be irrigated at the rate of 2 or 3 acre-inches per acre per day, cannot profitably be sub-soiled. Even some of the heaviest types of soil on which walnuts are planted, such as the Yolo clay loam in the Whittier section, will absorb 3 or more acre-inches per acre per day without cross furrowing, with ordinary cultural practice, combined with annual plowing. Many acres of this type as well as sandy loam soils have been sub-soiled in the past, probably at a net operating loss to the owner. Each piece of land must be judged on its own merits, regarding the irrigation experience thereon, and the possible benefits which may be derived by sub-soiling. We are convinced that there have been many cases of severe injury to mature trees by sub-soiling and cutting the roots.

COVER CROPPING

The beneficial effects of plowing under green-manure crops, as measured by the crops of annual plants which are later grown on the same ground, cannot be used as a safe guide in theorizing on the effects of this practice on walnut trees. In the case of annuals, there is no competition between the cover crop and the primary crop. Even with annuals, much of the benefits ascribed to the cover crop may have been due to crop rotation, as has been shown by various experiments which were so laid out as to measure this latter factor. Again, the root zone of many of the annual crops which have been used to indicate the effect of cover crops upon the productivity of the soil, corresponds more closely to the root zone of the cover crops than to that of the very deep-rooted walnut trees.

The practice of cover-cropping walnut groves prevails in probably somewhat less than 50 per cent of the total area of bearing groves. Many groves which are not sown to cover crops produce a volunteer growth of various annual plants, such as bur clover, lupins, wild oats, and filaree, during the rainy season.

Water Requirements of a Cover Crop.—Though we have no definite field trials to inform us concerning the effects of cover crops in walnut groves, a discussion of some of the factors to be considered may be useful. Possibly the primary factor is the problem of supplying sufficient irrigation water for the walnut trees and the cover crop

combined. While it is true that walnut trees do not draw very heavily upon the soil moisture during the winter months, yet it is highly important to have the water content of the soil somewhere near the field capacity during the entire winter. It is a mistake to allow a winter cover crop to deplete the soil of its necessary moisture. There should be no misconception about the saving of soil moisture because of the shade of the cover crop. This shade and the possible conservation of moisture in the few surface inches of soil, is hardly worthy of mention, compared with the soil moisture necessary to produce the cover crop itself.

Fig. 23.—A cover crop of melilotus clover (*Melilotus indica*) ready to plow under in late March. (From Bulletin 332.)

The actual water required to produce a fair crop of the several plants commonly used as cover crops in California has never been carefully studied, so far as is known to the writer.

From several cases observed it seems probable that the growth of a legume cover crop if grown to maturity (stage of full bloom) should be expected to require from 20 to 24 acre-inches per acre of rainfall and irrigation water combined. The winter rains alone are seldom sufficient to meet the requirements of the trees under clean cultural conditions. In practice, therefore, this will mean from three to four irrigations during the winter and early spring, in localities receiving only 10 to 15 inches of winter rainfall. (See "Irrigation.") It will suffice at this time to remind the reader again that there should be ample water available to grow the winter cover crop, and that after

the plowing in the crop, the walnut trees should be given a thorough irrigation at the commencement of their early spring growth unless the rainfall has been above normal. If the requirements of the cover crop alone are considered, at the time of plowing the subsoil may be entirely too dry to promote an early vigorous growth of the trees and nuts, even though the surface soil is moist enough to plow with a moldboard plow.

Effect on Physical Condition of the Soil.—One of the benefits derived from the use of cover crops in walnut groves has been the improvement of the physical condition of the heavy soils as a result of the incorporation of large amounts of organic matter. The experiences of many observing farmers seem to agree that the clay loams are made more friable and the irrigation water penetrates them much more readily when cover-cropping is practiced. The latter point, with reference to the deeper penetration of the irrigation water, may alone justify the use of cover crops on certain soils.

Planting of the Crop.—The legume cover crops most commonly grown in walnut groves during the winter months are bur clover, melilotus clover, and purple vetch.

The seed may be drilled in, or sown broadcast, and harrowed lightly with a spike-tooth harrow. The amount of seed required per acre is as follows:

Melilotus clover, or bur clover	20–30 lbs. per acre
Vetch	70–80 lbs. per acre

It is essential to plant the cover crop as early in the fall as possible after harvesting the nuts, in order that it may make a good start before the cold weather commences, and thus make sufficient tonnage by the middle of March.

Figure 23 shows a good crop of melilotus clover ready to turn under in late March. Cover crops are occasionally disked under. A cover crop disked under improves the physical condition of the surface soil, but may not disintegrate as rapidly as if it were plowed under and thus incorporated with soil which is kept more constantly moist.

IRRIGATION

Before discussing the irrigation of any crop, it is well to understand the extent and distribution of the root system of the crop in question. It is a commonly held opinion that walnut trees are very deep-rooted when grown on the majority of the orchard soils of southern California. In treating the matter of irrigation, the following

discussion may be taken to apply to the volume of soil included in the first eight feet from the surface of the ground. The discussion is confined to this depth of eight feet, not because it is judged that this is necessarily the absolute limitation of the root system, but because observations have shown: first, that the root-feeding area in many groves extends to at least this depth; second, that first-class crops can be grown when only the first eight feet of soil are considered; and third, if many of the walnut growers observed and frequently examined this volume of soil, they would improve their irrigation practice.

Winter Irrigation.—Successful walnut production in southern California and throughout the San Joaquin Valley in central California requires close attention to the moisture content of the soil practically the year around. In these districts the normal rainfall will not usually penetrate to a depth of eight feet in the soil types most frequently found in walnut groves. The winter rains are distributed over four or five months, and usually come in relatively light showers. This condition makes the loss by surface evaporation rather large in proportion to the total rainfall. Many groves have a cover crop or weed growth in them during the winter, which continually dries out the surface soil and by using the soil moisture prevents the deep penetration of the rain. Observations have been made in Riverside County for a number of years which show that at an average penetration of from five to six inches of soil to an inch of rainfall is a fair average at the end of the rainy season, in most walnut groves.

If the soil mass throughout the root zone is not wet at the end of the rainy season, and at the beginning of the growing season for walnut trees, the available irrigation water in many of the districts is insufficient to thoroughly wet this volume of soil after the rapid reduction in soil moisture commences coincident with the growth of the trees. Even in the many walnut groves which are irrigated during the winter time, the majority of the acreage is not thoroughly wet throughout the deepest portion of the root zone, except during years of heavy rainfall.

The relationship between adequate soil moisture during the early spring and the size of the walnuts produced subsequently is clearly shown by a study of the annual winter rainfall records and the percentage of number one nuts produced.

The data used in making this study were taken from the rainfall records during December to March, inclusive, from the Weather Bureau observation stations at Santa Barbara, Los Angeles, Pomona,

Riverside, and Tustin. During the nine rainy seasons, 1914–15 to 1922–23, inclusive, the average rainfall at the above stations has varied from 63 per cent of normal to 167 per cent. During this same time the percentage of number one seedling nuts (for details of grading nuts see page 109) has varied from 77 per cent to 96 per cent. The tendency for the years of heavy rainfall to be followed by a production of a large percentage of big nuts is shown by figure 24.

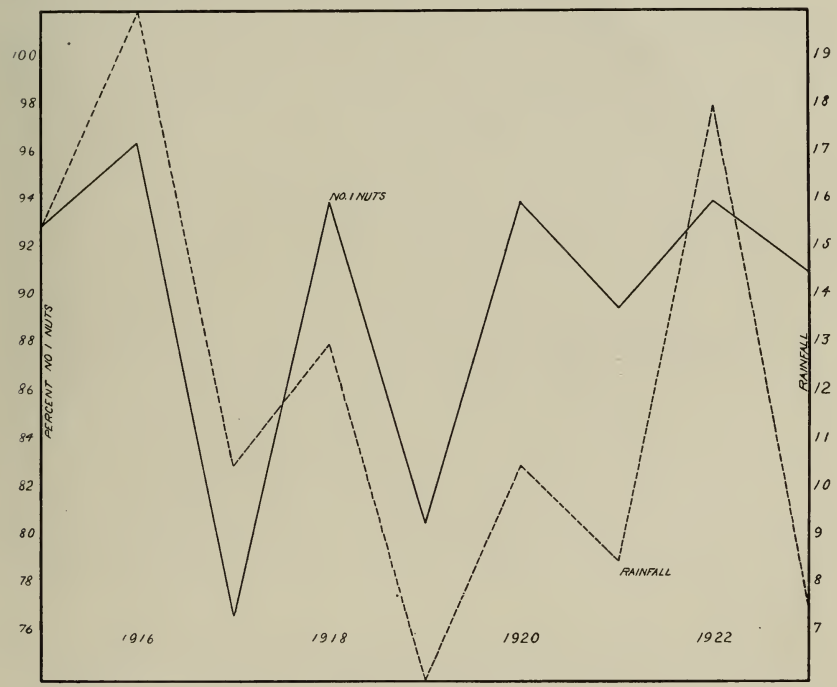


Fig. 24.—Yearly percentage of No. 1 grade seedling nuts sold by the California Walnut Growers Association and the mean winter rainfall from December to March, inclusive, in the several walnut-growing districts.

Although the curves may not be considered parallel, they do tend to move in the same direction. There are many factors besides *total* winter rainfall which operate to affect the soil moisture available for tree and crop growth during the early spring. Among these are distribution, amount per storm, weather conditions between storms, and season of rainfall, together with the demands upon the moisture by cover crops or weed growth. These may all bear more or less upon the percolation of the water into the soil and thus, finally upon the amount available to the walnut tree. Again, many walnut growers practice winter irrigation. In such cases, the volume of rain may not be a

limiting factor. It is hardly to be expected, then, that the lines would be parallel during the entire period; the fact that they tend in the same direction the majority of the seasons represented is unmistakable.

The fact that the lines cross between 1917 and 1918 may be due to the especial effectiveness of the rain of 1917–18 season in percolating deeply into the soil. During this rainy season, the rains came very late and extended over a short period which lessened the comparative loss by surface evaporation. Most of the rain fell in February and March and thus the weed growth in the groves was not started until a few weeks before they were plowed, this also abnormally favored the effectiveness of the rains in promoting the growth of the walnuts.

The chief thing that can be learned from this is the value of soil moisture in the early spring in producing large nuts. If this is a correct analysis of the facts presented, the practice of winter irrigation of walnut groves, which is followed to a great degree in some districts, should become a universal practice during the winters of scanty rainfall. Winter water applied at the rate of 6 to 12 acre-inches per acre is considered essential during years of subnormal rainfall. With such a demand for water in any walnut-growing district many of the groves must be watered before it is known whether the season will prove to be relatively dry or not; if every grower postpones winter irrigation until its absolute need is evident the demands on the water systems will exceed the supply. The use of winter irrigation water to supplement the seasonal rainfall may be looked upon as an insurance policy against winter drought and the resultant small percentage of large nuts.

Even though occasional years occur when the total winter rainfall is sufficient, a study of available weather records show that the extra expense of irrigation will probably pay big returns about five times out of nine, and will be profitable to some degree about nine in every eleven years. This certainly justifies the practice as insurance.

Irrigation in Relation to Seasonal Growth.—In discussing the practical irrigation of walnut trees throughout the growing season, perhaps the subject can be most clearly presented if the water requirements of the crop are considered from the beginning of the growing season in the spring, through the summer and harvest seasons. Unlike most fruit crops, the walnut is grown for the seed of the plant instead of for any edible, fleshy portion which surrounds the seed. Experience in growing stone fruits, such as peaches, shows that the size of the fruit may be greatly influenced by irrigation water applied late in the seasonal growth of the fruit, long after the pit has hardened.

This late increase in the size of the fruit is caused by the increased thickness of the fleshy or edible portion of the fruit, without any increase in the size of the pit itself. The growth of the walnut compares with the growth of the pits of the stone fruits, all of which reach their full size long before harvest and before the shell is fully hardened. The walnut shells of most of the varieties begin to harden about the middle of June.

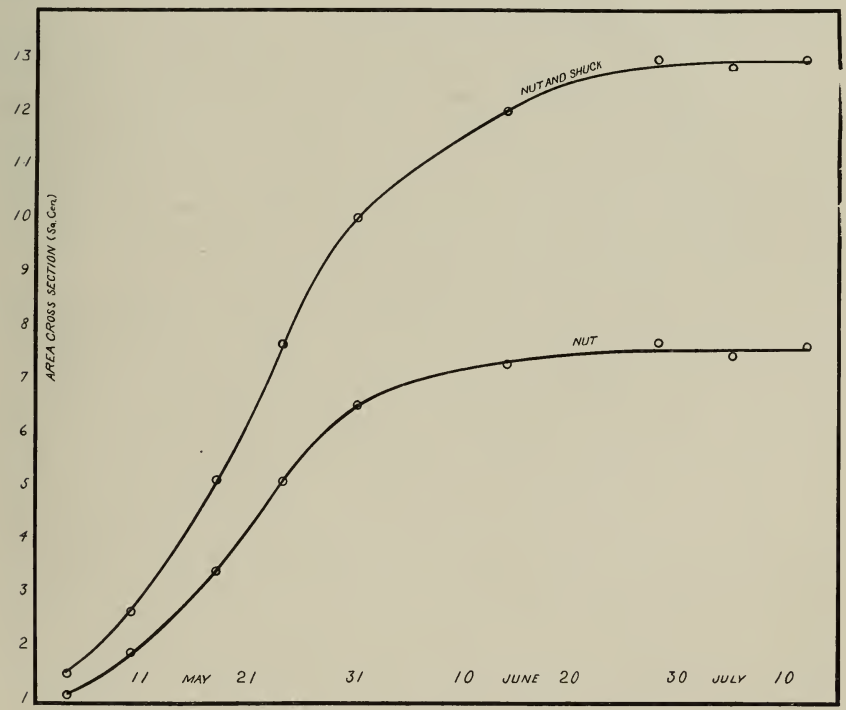


Fig. 25.—Mean weekly growth of Placentia walnuts from May 3 to July 12, 1923. (Expressed as the area of the cross section, which is in direct relation to volume.)

The most rapid growth of the walnuts takes place during the five or six weeks immediately after the blossoming period. It has been shown by field trials and by general observation that a shortage of soil moisture in a walnut grove during the early part of the growing period will be followed by a production of a large percentage of small walnuts. A study of the growth of Placentia walnuts was made during the 1923 season, the results of which are shown graphically by figure 25. The production of a large percentage of large nuts is so essential to successful walnut culture, that the details of the obser-

vations set forth in figure 25 may well be included in a consideration of the irrigation needs of this crop. Just when this period of rapid growth takes place and when it ends, is of prime importance to the walnut grower. At the end of the rapid growth "the die is cast" so far as the size of the walnut then on the tree is concerned. No amount of mid-summer or late irrigation water will make a particle of difference in the size of walnuts after the shell begins to harden so that it is cut with difficulty with a knife.

In obtaining the data presented in figure 25 random samples of 100 nuts were picked weekly in a similar, careful, systematic manner from a group of Placentia trees. These nuts were cut across their largest diameter between the stem and blossom end. Records were kept of the average size of the nuts, as well as of the average size of nuts and shuck *combined,* for the growing season. The actual diameter measurements have been transformed into cross-section measurements to show more clearly the trend of growth.

The curve shows the relative growth from May 3 to July 12. The trees bloomed 10 to 14 days before the observations commenced, at which time the small nuts were 1.2 centimeters ($\frac{7}{16}$ of an inch) in diameter. The curve shows that a rapid increase in size of the nuts took place from May 3 to May 31. After May 31 the curve flattens out and only a small growth is made up to June 28. After June 28 the differences in average size of all the samples measured were within the range of probable error in random sampling, and therefore show no increase in size after that date. The shuck, however, which corresponds to the edible portion of a stone fruit, made more relatively late growth than the nut: the growth curve for the shuck did not flatten out much until the last of June. By June 14 the average size of the sample was equivalent to the minimum size of a Large Budded nut.

By again referring to the curve it may be clearly seen how little actual growth took place after this size was reached. *The cross-section size of the samples of Placentia walnuts* increased 483 per cent during the 28 days from May 3 to May 31; and increased only 18 per cent during the following 28 days.

It must be clear from these figures that any irrigation water which is to affect the size of walnuts should be in the ground during the month of May, and the earlier it is applied during the month, the more effective it will be.

The winter irrigation serves also to supply the needed early spring moisture for the growth of the trees. Aside from the small amount of

moisture transpired by the dormant trees and lost through the surface evaporation of the soil, the bulk of the winter irrigation water is available for the tree's use in the spring, provided it is not largely used by cover crops or weeds before the trees begin to grow. Observations of the soil moisture present by means of a soil auger or soil tube which will reach to depths of 7 or 8 feet, should at least begin at the time when the trees start to leaf out. If the winter rains plus the winter irrigation do not percolate to a depth of eight feet during the winter and late spring, it is advisable to apply the first spring irrigation sometime in April. At this season of the year the trees are beginning to leaf out and the young nuts should soon be rapidly increasing in size. Filling the subsoil with moisture at this season makes a reservoir for the tree roots to draw upon during the early part of the summer, while the nuts are reaching their full size. It should not be inferred from this that soil moisture which penetrates below the root zone is drawn upward into the root zone by capillary action as the growing season advances. Such capillary action is probably negligible unless a water table is present.

A series of experiments carried on by La Rue and Batchelor[16] points out the results of adequate irrigation in contrast to lack of proper irrigation in relation to seasonal growth. Three plots were laid out, comparable with the three conditions which are often found in commercial orchards.

In one plot (plot 3) the soil moisture was maintained between the wilting point and field capacity of the soil to a depth of seven feet except possibly during the harvest season and early winter.

In another plot (plot 4) the soil moisture was maintained between the wilting point and field capacity of the soil to a depth of seven feet except from the first week in July until the first week in September. During this latter period the soil was allowed to become dry.

In still another plot (plot 5) the soil moisture was maintained between the wilting point and field capacity of the soil to a depth of seven feet, from July to September inclusive. This plot was therefore relatively dry during the first part of the growing season. All three plots received the same total amount of water.

The effect of these three irrigation practices upon the nuts from the respective plots is shown in table 10, and may be summed up as follows:

[16] La Rue, R. G., and L. D. Batchelor. Irrigation of walnut trees in relation to the quality of the nuts. Diamond Walnut News, 10(2):3. May, 1928.

Plot 3, in which adequate moisture was available at all times, produced a good crop, in consideration of the adverse season, with respect to both size and quality of the nuts. Plot 5, which received no water until July, produced only 18 per cent large-sized nuts in contrast to 64 per cent large-sized nuts on plot 3, and 21 per cent babies as against 2 per cent babies on plot 3. The quality as compared with plot 3 was fairly good. There were 27 per cent culls on plot 4 and 26 per cent culls on plot 5 due to exterior appearance as contrasted with 17 per cent culls due to exterior appearance on plot 3. Crack tests showed 26 per cent blanks, shrivels, and molded combined on plot 4 as against 14 per cent on plot 3.

The results from the irrigation applied in early spring were not so good as in the case where the irrigation was applied in the winter prior to the starting of spring growth.

TABLE 10

PERCENTAGE OF SIZES AND QUALITY OF WALNUTS RESULTING FROM DIFFERENT SEASONAL APPLICATIONS OF IRRIGATION WATER

Plot	Nature of season of irrigation	Packing-house grades				Orchard-run crack test eliminating class in column 5	
		Size grade			Culls exterior appearance	Culls, moldy, blank, and shriveled	Sound
		Baby	Medium	Large			
1	2	3	5	6	6	7	8
3	Adequate through growing season	2	17	64	17	14	86
4	Dry latter part growing season	3	20	50	27	26	74
5	Dry early part growing season	21	35	18	26	15	85

The lack of soil moisture early in the growing season caused small-sized nuts, and the lack of soil moisture during June and early July resulted in very poor quality as measured by the shriveling of the kernels. Table 11 shows the yield and estimated gross income for each plot.

Depth of Soil to Irrigate.—It should be the aim of the walnut grower to keep all the soil from the surface to a depth of at least seven to eight feet well supplied with moisture from early spring until early fall. In accomplishing this it should be borne in mind that the root system of the walnut tree is distributed throughout this entire seven

to eight-foot depth of soil and in many cases much deeper. However, the soil moisture is extracted much more rapidly from the surface three or four feet of soil than from the area below this where the roots are less numerous. Such observations may be interpreted as showing that the roots are more numerous in the upper three or four feet of soil than in the area below this. For this reason it may be desirable to apply only sufficient water to wet the upper root zone at one or more of the irrigations during the summer months. This principle applies especially where there is little or no change in the water-holding capacity of the soil from the surface to the lower root zone. If, on the contrary, the lower portion of the root system is surrounded by a soil with a much greater capacity to hold moisture than the surface soil, it may be necessary to use precaution to prevent excessive irrigation of the lower root zone.

TABLE 11

Yield and Estimated Gross Income per Acre for Each Plot

Plot	Yield in pounds	Estimated gross return per acre	Loss due to unseasonal irrigation compared with plot 3
3	1,760	$357.28	.....
4	1,230	194.46	162.82
5	1.188	167.75	189.53

Figure 26 shows the trend of soil moisture in a full-bearing walnut grove located in the coastal district, growing on a Yolo loam. The water-holding capacity does not change greatly throughout the first seven feet from the surface. It can be seen from this figure that the soil moisture was not removed as rapidly from the lower root zone as from that portion nearer the surface. The winter and early spring irrigations thoroughly wet the entire root zone, but it was not necessary to apply so much water during the latter part of the growing season as was applied during the winter irrigation. The slower drying out of the soil through the lower root zone made very heavy applications during midsummer unnecessary. The whole soil mass was kept above the wilting point throughout the growing season. In the case of groves located on such soil types as the Hanford fine sandy loam or the Hanford sandy loam, the conditions are different from the case above described on the Yolo soil. The Hanford types are commonly underlain by a coarse sandy strata which holds less water than the surface soil. With fewer roots in this lower area it will

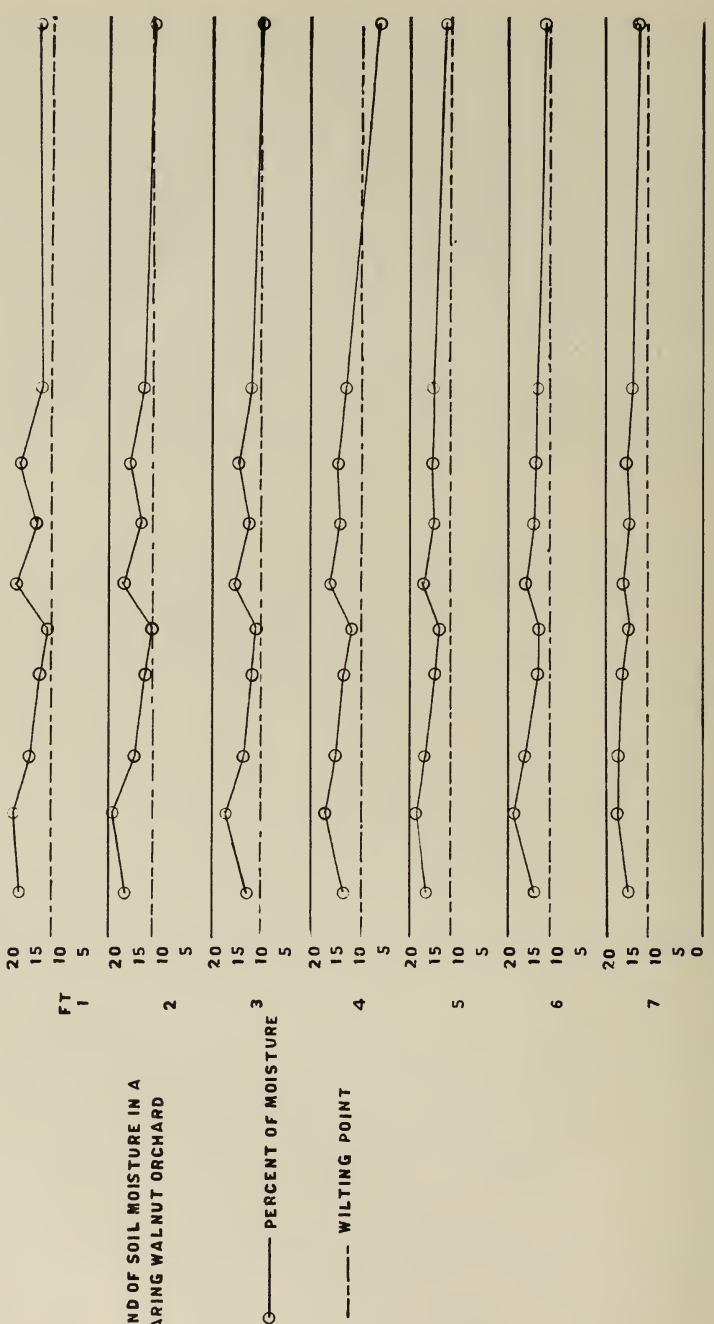


Fig. 26.—The trend of soil moisture in a full bearing walnut grove, in relation to theoretical wilting point.

reach the wilting point more nearly coincident with the surface three or four feet of soil, than will the soils of the Yolo series. In the former case the relatively fewer roots in the subsoil compared with the surface soil is somewhat compensated by the lower water-holding capacity of the lower area. Under such conditions it is usually advisable to apply sufficient water to wet the lower root zone at each irrigation. On the Hanford series and other soils with a subsoil lighter than the surface soil, there is less probability that the grove will be overirrigated, because of better sub-drainage than the Yolo series.

Frequency of Irrigation.—The soil moisture due to early spring irrigation, winter rains, and winter irrigation, should be supplemented by water applied in midsummer to promote the filling of the nuts with plump kernels. This may require three applications of water in June, July and August, respectively, or possibly only June and August, according to the type of soil and the climatic conditions. The light sandy soils will require more frequent irrigation than the heavier soils, while the walnut groves in the hot inland valleys will require more water than those on the coast, which are frequently bathed in heavy fogs and where the daily temperature is relatively low. Detailed directions for the irrigation of walnut groves cannot be presented in a general treatment of an industry which is found under such widely divergent conditions. Emphasis should be laid, however, upon the need of a continuous supply of soil moisture during the winter months and from the time the tree leafs out in the spring, up to and including the beginning of the harvest period. Just as the early spring moisture is essential to the production of large nuts, and the midsummer water to the full development of the kernels, ample soil moisture in early September is necessary to promote the normal development of the nut to the point where the husk cracks open and the nut drops free to the ground, leaving the husk temporarily attached to the twigs. The absence of sufficient water during the final development of the crop is almost invariably associated with the sticking of the husks to the nuts, sunburning, and a consequent high percentage of cull nuts. The shells of the nuts which crack out of the husks naturally are mostly of a bright straw color and free from stains, while those to which the husk adheres are often stained, and may even be classified as culls, if the stain is too deep to be obliterated by bleaching.

It is a common observation of practical walnut growers that it is more difficult to obtain deep percolation of the irrigation waters in

midsummer than in spring. This condition is largely due to the fact that subsoils have not been thoroughly moistened in the early spring and are allowed to become too dry before irrigation in mid-summer. This excessively dry soil resists the entrance of moisture to a much greater degree than a soil which is moderately damp at the time irrigation water is applied. This phenomenon of the movement of soil moisture into soils of different moisture contents has been observed often, both in the laboratory and the field. Figure 27 illustrates an orchard being irrigated by the dike and check-furrow system. This prevents run-off when a large volume of water is used and secures deep penetration of moisture.

Fig. 27.—This system of the dike and check furrow irrigation is used to prevent run-off and obtain a deep moisture penetration. (From Bulletin 332.)

Just when the time arrives to begin spring irrigation and when more water should be applied in midsummer depends upon the cultural and irrigation practice which has prevailed during the winter and early spring. If the land has not been winter irrigated, or if a cover crop has been grown without adequate water, the subsoil may already be dried out below the wilting point by April 1. It is impossible to lay down any hard and fast general rule that can be followed without examining the soil. Every walnut grower should study and frequently observe the moisture condition of the subsoil as well as the surface soil in the walnut grove. Groves which are served by pumping plants may be irrigated as needed. For those which depend upon a mutual gravity water system it is necessary to arrange the water

schedule in advance on the basis of close observation of their needs in the past.

The subsoils can be examined and readily sampled by means of a soil tube. For the intelligent irrigation of a deep-rooted crop like the walnut, a soil tube is as necessary as an irrigator's shovel. Opposite sides of a ten-acre tract may take water differently in the subsoil,

Fig. 28.—A farmer examining the subsoil in his grove to a depth of 8 feet. (From Bulletin 332.)

while the surface soil seems uniformly irrigated. Only by the use of a soil tube or auger can the farmer make any more than a poor guess at the soil-moisture conditions throughout the deep-root zone. Figure 28 shows a farmer examining the subsoil in his grove to a depth of eight feet.

Amount of Water per Irrigation.—The amount of water necessary to wet down through the root zone will depend largely upon the type of soil and the degree of dryness which prevails before the water is applied. It will require between the extremes of 1 and 2½ acre-inches per acre for each foot depth of soil, to bring the moisture from the wilting point or below, up to the normal field capacity of the soil. This may be taken as only a very general rule, however, for a clay-loam soil which has been allowed to become very dry may require much more than a sandy loam only moderately dried.

If, for example, it is desired to apply water enough on a light sandy loam soil to penetrate to eight feet from the surface, it may require 10 acre-inches per acre ($1\frac{1}{4} \times 8 = 10$) if the subsoil, as well as the surface soil is dry at the beginning of the irrigation run. On the other hand, 6 acre-inches may be ample if the subsoil is not excessively dried. On land underlain by clay or gravel at less than eight feet from the surface, there is a likelihood that the root zone is shallower than in the preceding example and correspondingly less water per irrigation will be needed. It will probably require more frequent irrigation under such conditions, however.

The frequency of irrigations desirable will depend upon the age and the number of trees per acre, the soil type, the presence of inter-crops, climatic conditions, etc., all of which comes back again to the necessity of each farmer thoroughly studying his soil conditions by means of a soil tube.

Danger of Excessive Irrigation.—A knowledge of the amount of water used is as important as studying its movements through the subsoils. It may prove a greater mistake in the end to apply too much water than not to apply enough. Water applied in excess is lost in the underground drainage and may create a water table by reason of such seepage water, to the eventual detriment of lands at lower elevations if not to the land which is being overirrigated. There are literally thousands of acres of good walnut land in California which have been ruined by excessive irrigation of higher lands. Many fine groves have been reduced to mediocrity by a rise in the water table (see "Drainage and Alkali Injury," page 19). Much depends upon the nature of the deep soil formations. The far-sighted intelligent irrigator who looks upon his walnut grove as a permanent investment, will study the movement of soil moisture, not only throughout the root zone, but farther, and inquire into the possible loss of water by deep percolation beyond the reach of the walnut trees.

Fig. 29.—If the lower half of the orchard is check-furrowed, the run-off will be reduced and the added pressure of deeper water in the furrow will help to force the moisture into the dry subsoil. (From Bulletin 332.)

Fig. 30.—If the water will move into the soil readily the use of deep furrows and the wetting of as little of the surface as possible will reduce the moisture loss by evaporation to a minimum. (From Bulletin 332.)

Methods of Application.—The actual method of applying the water to the soil must be adapted to the conditions of each case. Three different systems of applying water are illustrated by figures 27, 29, and 30. The advantages of the respective methods are briefly stated under each illustration.

INTERCROPPING

Intercropping of young walnut groves is the general practice. This practice has usually proved very successful in making the land support the orchard before the walnuts come into profitable bearing.

Annuals.—The best intercrop to use will depend somewhat upon local circumstances. In the bean-growing districts and in cases where the walnut groves are large enough to justify the maintenance of necessary machinery, beans are an ideal intercrop for the young grove. The bean is a legume and requires thorough cultivation. These facts contribute to the best conditions for the development of the young trees, if sufficient irrigation water is available for both crops. The bean straw can be plowed under, which is an advantage in soil improvement.

Beans may be grown in a grove until the trees are eight or ten years old as shown in figure 31.

Outside the bean districts, the choice of intercrops largely depends upon the market conditions for the proposed crops. Several of the vegetables commonly grown for canning factories may be profitably grown in the young orchard without harm to the trees. Such crops as tomatoes, peppers, and string beans are often used. Figure 32 shows a vegetable intercrop in a young walnut grove interplanted with peaches.

Intercrops of corn, milo, squashes, and pumpkins are not so well thought of by many experienced walnut growers, because of their apparently harmful effect upon the trees. Milo, especially, is generally considered a bad intercrop for walnuts. Milo is a very drought-resistant crop with a relatively low water requirement. It will therefore develop a first-class crop under soil conditions unfavorable to the best growth of the walnut trees. The thrifty appearance of the milo may deceive the farmer concerning the condition of the walnut roots. Only the closest students of irrigation should attempt to grow this crop in a walnut grove, and it may be of doubtful value even then.

Fig. 31.—Beans used as a profitable intercrop in a ten-year-old grove in a bean-growing district. (From Bulletin 332.)

Fig. 32.—A vegetable intercrop in a young walnut grove which is also interset with peaches.

Alfalfa.—The use of alfalfa as an intercrop is occasionally seen in groves which appear to be fairly productive. The effect of this crop combination has been studied by a field trial in Orange County. Figure 33 shows the average production per tree during two years before and five years during the trial on a three-acre plot intercropped with alfalfa, compared with an adjacent plot of the same size which was

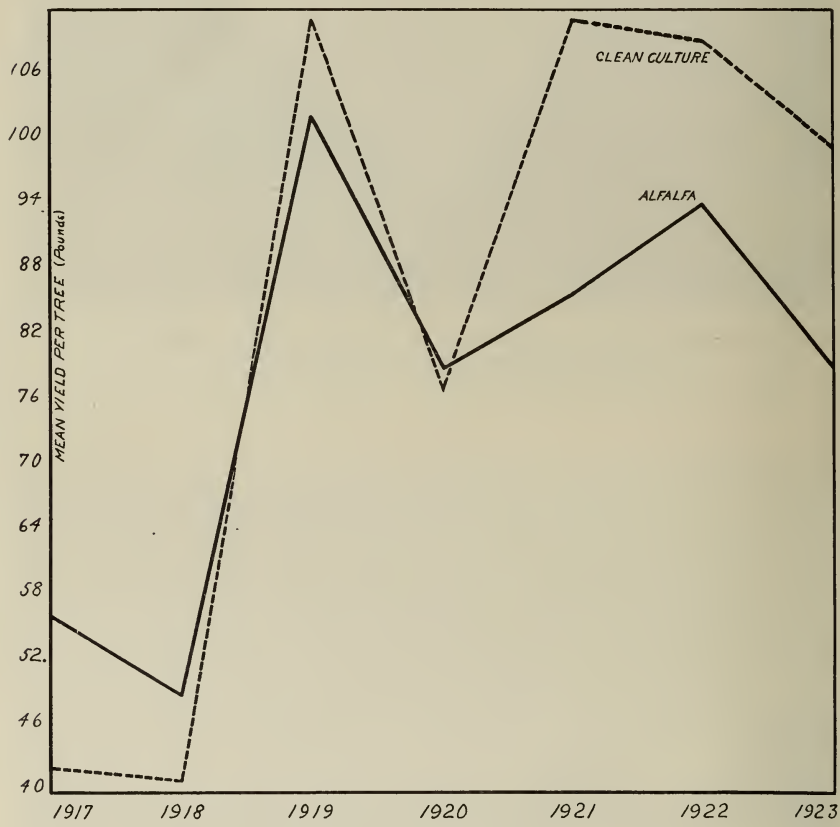


Fig. 33.—Annual average production per tree before and after intercropping with alfalfa, compared with a plot which has been continuously clean cultivated. Alfalfa planted in the fall of 1918.

clean cultivated summer and winter. The alfalfa was planted during the fall of 1918. The yield records of 1917 and 1918 show that the alfalfa plot was probably the more productive of the two before the experiment. During the five years of the experiment the production of the alfalfa plot was on an average 67 pounds (weight at harvest) per tree less than that of the clean-culture plot. Allowing for shrink-

age in curing of 15 per cent and using the respective current year's prices of nuts as a basis of calculation a loss of approximately $16.50 per tree or $200 per acre was caused by the alfalfa. The alfalfa was planted in the middles only taking up one-half of the ground in the grove as shown by figure 34. Crediting the alfalfa at a safe estimated production and at the ruling prices during the respective years, with due allowance for cost of production, the loss due to alfalfa was materially reduced. Even then the clean culture plot was the more profitable. The economic side of the question will vary from year to

Fig. 34.—Alfalfa intercrop in walnut grove covering only half the ground proved detrimental to the production of walnuts.

year with the prices of walnuts and alfalfa. The greatest interest is in the fact that apparently the alfalfa as an intercrop on one-half of the land was a detriment to walnut trees even though they are planted 60 feet apart. The cause of the bad effect is not entirely clear. An abundance of irrigation water was available and was used more freely than most walnut growers could afford to use water. Studies on the nitrate content of soils in leguminous cover crops compared with clean culture, lead to the belief that there was actual marked reduction of nitrate nitrogen in the soil of the alfalfa plots.

Fruit Trees.—If the grower has only a small plantation, not justifying the maintenance of bean machinery, and has not a ready market for a vegetable crop, the intercropping with a precocious fruit tree may be desirable. Peaches, prunes, and apricots are among the fruit

trees most commonly used in such schemes of intercropping. In many instances observed young groves interplanted with these fruits have made less growth than groves interplanted with beans. Nevertheless, in many cases, the fruit trees have been profitable and have made the orchard self-supporting while the nut trees were growing, thus outweighing, from a business point of view, the temporary check of the walnut trees. If fruit trees are used as an intercrop, the farmer must study his irrigation problem carefully to be sure the walnut trees are not robbed of their needed water by the companion crop. General observations indicate that the apricot tree is a keener competitor of the walnut than the peach.

There are several serious objections to interplanting with fruit trees. If clingstone canning peaches are used as an intercrop, they will require late summer irrigation to fully develop their crop, at which time water should be discontinued upon the walnuts. Some of the latest and most profitable varieties should be watered in late August and September in order to bring them to a good size for the canning factory. This late water on young walnut trees is very liable to keep the twigs growing so late that they will be severely injured by the early fall frost. Such a hazard will diminish as the walnut trees come into bearing; the drain of crop production acts as a regulator in slowing up the late summer growth, thus aiding the walnut trees to become nearly dormant at the season of early fall frosts. The prune has been a profitable intercrop with walnuts, but here the discordant water requirements are somewhat reversed, and do not become pronounced until both the prunes and the walnuts are in bearing. At this stage in the development of the plantation, when it is possibly from six to twelve years old, and before it seems economically sound to pull out the prunes, the late summer water requirements are opposite with these two crops. As the walnuts mature they should be irrigated so that they will be fully developed and so that the husks will crack open, producing a clean-shelled, plump-kerneled nut; irrigation of the prunes at this time is objectionable.

If either prunes or peaches are used as interplants it would seem advisable to plant the walnuts 30 ft. by 60 ft. and the fruit trees in solid rows in the middle of the interspaces. These temporary trees might be planted only 15 feet apart in the row, which would give enough fruit trees to the acre to make it worth while, and yet have room enough for heavy fruit production for a few years. This arrangement would permit irrigating only a part of the land, thus serving the water requirements of one crop without affecting its asso-

ciate crop very much. As the trees grow older, the roots become interwoven throughout the entire soil mass and gradually the advantages of this plan lessen, and the filler trees should then be pulled out.

FERTILIZATION

The walnut crop makes relatively small demands upon the plant food of the soil in comparison to other fruit crops. This may be illustrated by table 12.

TABLE 12

Plant Food Elements Withdrawn from the Soil by Various Fruits
Pounds Per Acre

Fruit	Amount of crop	Nitrogen	Phosphoric acid	Potash
Oranges	16,300	28.23	8.63	34.39
Lemons	18,900	28.53	11.52	50.84
Apricots	10,000	19.73	6.40	29.00
Walnuts	1,000	10.20	2.78	1 50

Field trials with various kinds and amounts of fertilizers applied to several walnut groves have been carried on by the University of California, cooperating with the Field Department of the California Walnut Growers Association.

Three separate trials far removed from each other on different soil types were continued for from five to seven years. The small differences between the several plots in the trials were all within the limits of error, so it cannot be said with confidence that the fertilizers have been in the least profitable or even beneficial.

Nitrogenous fertilizers have apparently increased walnut production on some types of soil where trials were conducted by farmers. Their use, however, should be considered an experiment, and only a part of the grove should be so treated until marked results are obtained on each individual property.

PRUNING

Like many of the fruit trees, such as apples or oranges, the pruning of the walnut tree has evolved into several similar systems of pruning practice (see page 51). In many groves pruning consists merely in the cutting off of the lower limbs which interfere with cultural practice.

The fact that few walnuts are produced in the centers of the old trees has suggested a moderate thinning out of the branches from year to year in an attempt to promote production more uniformly throughout the trees. Sunlight is necessary for the production and maintenance of fruit spurs, and without some thinning out practically all of the crop is produced on the outside twigs, in the tops, and on the sides of the trees. Some of the most successful walnut growers have adopted this sort of pruning as an annual practice, cutting out the water sprouts and the dead wood, thinning out the thickest growing portion of the top, and reducing the number of crossed limbs and weak crotches. In the absence of any systematic field trials this gradual and annual thinning-out process seems the most advisable.

This system of pruning should not include the heading back of fruiting limbs, as such a practice will promote a rapid growth of water shoots near the ends of the parts which remain, defeating the very attempt to shorten the limbs. If the limbs are too long and top-heavy on the sides of the trees, they should be cut out entirely, or cut off to lateral limbs, thus restricting in a measure the development of water shoots.

In all pruning operations with the walnut, care should be taken to cut the limbs off smoothly with a saw without leaving any stub. All wounds should be painted with a weatherproof paint. The walnut wood decays very readily and therefore any large cut exposed to the weather for a short period will surely become infected and start a decay which will eventually spread to the center of the tree. The framework of the tree thus undermined by so-called heart rot may be split by an overload of nuts, and be partially or wholly destroyed.

Old groves in which the trees are planted very close together should not be severely pruned to prevent the branches from adjacent trees interfering, but rather a number of the trees should be cut out, thus thinning out the grove itself. Figure 12 shows a close grove in which the lower branches have been periodically cut off, finally reducing the bearing area of the individual trees nearly 50 per cent. The production in such groves declines prematurely and does not respond to the pruning system. The greatest competition in closely planted groves is in the root systems of the trees. The only remedy is to remove the cause by taking out part of the trees. Figure 13 shows a grove which was thinned out by removing one-half the trees three years before the photograph was made. The old stumps are still standing. After three to five years a thinned grove may be expected to return to its production before the removal of one-half the trees.

After this interim decided gains are usually made over the former yields. Even though the trees have been pruned to an extremely upright position as have those shown in figure 12, after the grove is thinned out lower branches will grow and fill out to a more oval-shaped tree.

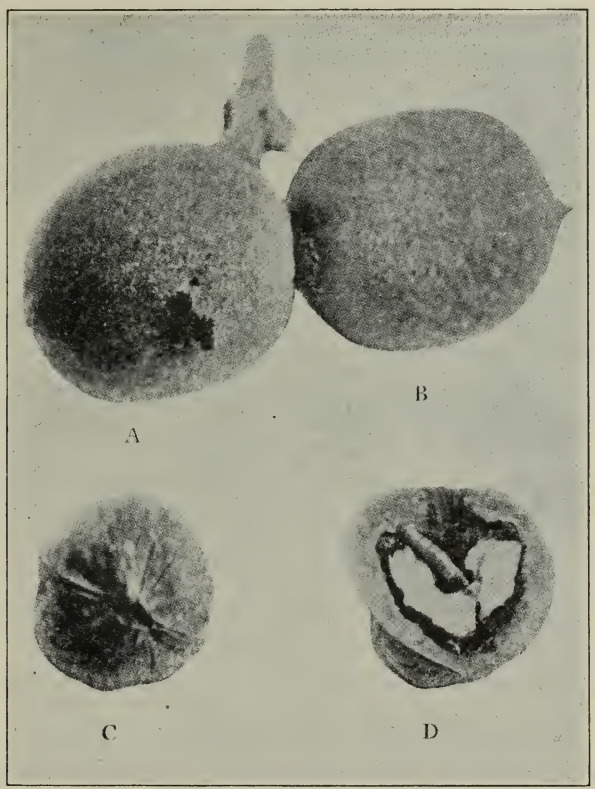


Fig. 35.—*A,* Appearance of green nut after worm has entered on open side. *B,* Codling moth worm usually enters green nut on the stem end as here shown. *C,* A round or oval opening on the stem end of the cured nut is almost certain sign that the worm has paid his respects inside. *D,* Section of walnut showing the codling moth worm. (From Bulletin 332.)

INSECTS AND DISEASES

The insects which are most commonly troublesome to the walnut are the codling moth (*Carpocapsa pomonella*), walnut aphis (*Chromaphis juglandicola*), red spider (*Tetranychus telarius*), and Italian pear scale (*Diaspis piricola*).

Codling Moth.—The codling moth has been known to infest walnuts in California since 1909, when it was first observed in the vicinity of Concord.[17] Since its first appearance, it has periodically become very troublesome in most of the walnut districts of California.

The injury caused by the codling moth to walnuts is similar to that seen in wormy apples. The worm eats a portion of the kernel of the nut and renders the remainder inedible. The manner of attack and entrance of the worm is clearly shown in figure 35.

Where the codling moth has been present in orchards in past years and the amount of infestation has been 5 per cent or greater, the trees should be dusted or sprayed with *basic* arsenate of lead between May 25 and June 20, and a second spray when necessary should be applied during the latter half of July.

If dusting is to be used, five or six pounds of dust[18] to the tree is required for trees of medium size, and 7 to 10 pounds for the largest trees. A thorough application should be made to cover all the nuts and all green parts of the tree.

For spraying, use 10 pounds of dry *basic* arsenate of lead to a 200-gallon spray tank. For a tree of average size, 20 gallons of spray is necessary, or 1 pound of arsenate of lead. For the largest trees 40 gallons of spray is necessary, or 2 pounds of *basic* arsenate of lead to a tree. All nuts on the trees should be covered by the spray. It is not necessary to spray the trunk and branches or any part of the tree where there are no nuts, unless the aphis is to be combatted at the same time. Spray guns should be used in order to reach all parts of the tree. Spraying will insure a higher degree of control of the codling moth than dusting, but the labor expense is somewhat more and it takes longer to cover a given acreage.

Aphis.—The aphis is a small yellowish plant-louse which feeds on the leaves and succulent growth by sucking their juices. This weakens the tree and causes it to produce less crop, lighter and smaller nuts, and imperfect shells. The foliage of a tree infested with this insect becomes covered with honeydew, a sticky secretion which turns black upon continued exposure to the air and is often covered with black smut fungus. The damage caused by the aphis varies from year to year. In some sections the damage is considerable every year, in others, only in exceptional years. The aphis usually disappears in the inland sections with the approach of extremely hot weather.

[17] Quayle, H. J. The Codling Moth in Walnuts. California Dept Agr. Mo. Bul. 9(3):64. 1920.

[18] Basic arsenate of lead is mixed with kaolin, which acts as a diluent and a carrier. Use only the standard commercial brands.

Where there is no codling moth, but the aphis is generally present in serious numbers, use tobacco extract diluted with some such substance as kaolin or hydrated lime. A material of this sort is especially prepared for aphis control. From 2 to 4 pounds of this material is necessary for a tree, according to its size. The best general time for such treatment is during the last week of May and the first two weeks of June. During years when the aphis occurs in large numbers, it may be advisable to dust a second time, during July or August. Do not wait until infestation is severe before applying dust, for material damage will have been done by the time the leaves are covered with honeydew. Begin to dust as soon as there is an average of ten aphis per leaf.

Combined Control for Aphis and Codling Moth.—Where past experience has shown that the codling moth, as well as the walnut aphis, may generally be present in large numbers, use a dust combination containing both tobacco and basic arsenate of lead. If spraying is to be practiced instead of dusting, add one pint of black-leaf forty to each 200-gallon tank of basic arsenate of lead as prepared for the codling moth.

Red Spider.—In some years the red spider does much damage to walnut trees in isolated instances. Injury is not usually apparent until the middle of the summer, when the leaves turn a dull but decided yellowish hue. A close examination at this time will show the presence of a countless number of red spiders, barely visible to the naked eye. If the attack goes on unchecked, the leaves will drop prematurely, injuring the quality of the current crop and the development of fruit buds for the future crop.

The most practical control measure is dusting with dry sulfur and hydrated lime, three parts to one, respectively. Spraying during the dormant period has not been found advisable in the past.

Italian Pear Scale.—The Italian pear scale (*Diaspis pirícola*) is found mainly in the northern walnut sections. The female scale is nearly circular, gray with a dark brown exuvia. The male is a slender, white, carinated scale with yellow exuvia. Their bodies are dark reddish purple. This scale is often overlooked owing to the fact that it is usually living under the lichens which grow on the bark.

Long-standing infestations may result in depressions in the limb and may cause a marked decline in the vigor of the tree.

Crude-oil emulsion sprays, to which seven pounds of 95 per cent caustic soda to every 200 gallons of spray mixture have been added to remove the lichens, is a very effective spray material.

Walnut Blight (*Bacterium juglandis* Pierce).—The walnut blight is by far the most destructive disease affecting the walnut crop. The prevalence of this disease, as previously stated, varies considerably from year to year, and is usually much worse in the foggy coastal districts than in the inland valleys. In years of bad outbreaks, the blight has probably destroyed from 15 to 20 per cent of the crop.

It is a bacterial disease which attacks the young and tender growth and spreads to the more mature wood, causing the affected areas to turn black and die. Under favoring conditions, the disease is especially destructive to the nuts. If it attacks the nuts early, it causes them to turn black and drop off when one-eighth to one-half of an inch in diameter. It causes full-sized nuts to become blanks, and may make full-grown nuts unmarketable, except as culls by reason of staining the shell. It shows on the nut as black spots most prevalent at the calyx end, but often scattered over its entire surface.

At present there is no control known for this disease. Attempts to lessen the prevalence of the blight by spraying are being made at this time by investigators in this institution.

Some of the varieties now being propagated are more resistant to blight than the average seedling tree. At present the greatest likelihood of relief from this disease lies in securing resistant or immune varieties.

Melaxuma.—This troublesome disease of the walnut tree has occurred in serious outbreaks in Santa Barbara, Ventura, Los Angeles, and Orange counties. Careful studies of this disease were made and reported in 1914 to 1915 by Fawcett.[19] The nature and treatment of the trouble may best be summarized by quoting from the above-mentioned author.

> Because of the oozing of dark watery material to the surface of the affected areas, this disease is often confused, under the name of "black sap," with sunburn, frost injury, injuries to the bark in cultivation, injury from the decay of wood at places where limbs have been cut off, and other troubles in which a black "sap" may ooze out during the active growing period of the tree. It should not be taken for granted, therefore, that, because a black ooze is seen on the trunk or larger limbs of a walnut tree, Melaxuma is necessarily present.
>
> As the term "black sap" has already been used by R. E. Smith to designate a result of sunburning, this name was not considered suitable for the disease here being considered. The word *Melaxuma*, derived from two Greek words meaning "black" and "juice" was therefore adopted, and is now in fairly common use to designate the disease herein described.

[19] Fawcett, H. S. Melaxuma of the walnut. California Agr. Exp. Sta. Bul. 261:131–148. 1915. (Out of print.)

Fig. 36.—One of the first evidences of Melaxuma. The black sappy ooze has appeared at the outer edges of the killed bark at the crotch shown by the arrow. The bark between has been killed and pycnidia of *Dothiorella* have already appeared on the surface of part of the killed bark. (From Bulletin 261.)

Melaxuma shows its effect most strikingly during the summer after the growth is well started. On trees severely affected at this time, there will be seen large black sunken cankers on the trunk and larger limbs and often a sudden wilting of the smaller limbs and twigs. This sudden wilting of the smaller limbs is so different from the effects of walnut blight or bacteriosis that it is easily distinguished from that disease.

The most common location for Melaxuma cankers is at the crotch of the tree where the first limbs join the trunk. The first evidence of the disease is often a black area like a dab of tar on the otherwise grayish bark [as shown by figure 36]. This is due to the staining of the bark by a black watery substance that forms under it. The diseased area later becomes slightly sunken, shrinks, and cracks. The "black sap" then oozes out in considerable quantities and stains the bark as it runs down the limb or trunk. The wood underneath is discolored for a short distance and this discoloration usually extends beyond the margin of the killed bark. The diseased areas, as a rule, do not extend entirely around a limb in one season, but affect only about one-third or one-half the circumference of the bark. Later in the summer or fall the increase in the size of the areas is slower and often appears to stop. One part of the margin of the canker may dry out and begin to heal over, while the other continues to advance or remains stationary until the next spring, when it begins to advance rapidly again. A few cankers on large limbs of vigorous trees may even heal over without treatment. More often there is an enlargement from year to year, which in two or more years extends entirely around a large limb, causing it to wilt and die. These limbs occasionally wilt suddenly, the dried-up nuts and leaves remaining attached for some time. When cankers occur on the trunks they generally follow some injury to the bark made by a plow cultivator, or other instrument used in the cultivation of the orchard.

From the observations and results of experiments so far made, the following tentative treatment is suggested:

Cut out the cankers that have not gone too far on the trunk and larger limbs and disinfect the wounds thus made. [See figure 37.] The dead and discolored bark should be cut away, getting a little beyond the margin of dead tissue. If the cankers are not large and the wood underneath has not been stained deeply, it will pay to cut out all the discolored wood, as well as the bark. Probably one of the best disinfectants to apply to the wound is the Bordeaux paste[20] that is recommended for lemon gummosis. If the canker is large and has been in the tree a long time, the wood may be stained so deeply as to render

[20] *Bordeaux paste.* The formula for Bordeaux paste is as follows: 12 pounds of blue stone (copper sulfate) dissolved in 8 gallons of water in a wooden, earthen, or glass vessel; and 24 pounds of quicklime slaked in 8 gallons of water. When the lime is cool, stir together about equal parts by volume of each, for making enough mixture to last for one day only. The bluestone is most easily dissolved by suspending it in a sack at the top of the water. If the bluestone is pulverized and suspended in warm water, it dissolves rapidly. Good lime that is not air-slaked should be used, and after slaking it with the water, it should be allowed to cool before being used in making paste. If covered to avoid evaporation each ingredient will keep indefinitely, but after mixing, the paste slowly deteriorates. Where it is being used over a number of days or weeks, just enough of the wet slaked lime and the bluestone solution should be mixed to make paste enough to last for one day, leaving the remainder unmixed in separate vessels. It may be applied with large brushes, as in whitewash.

the work of cutting out all discolored wood too expensive. If the canker has practically girdled the limb, the limb had better be cut out.

Crown Gall (*Pseudomonas tumefaciens*).—Crown gall, which is caused by a bacteria, is found on many of the deciduous fruit trees.

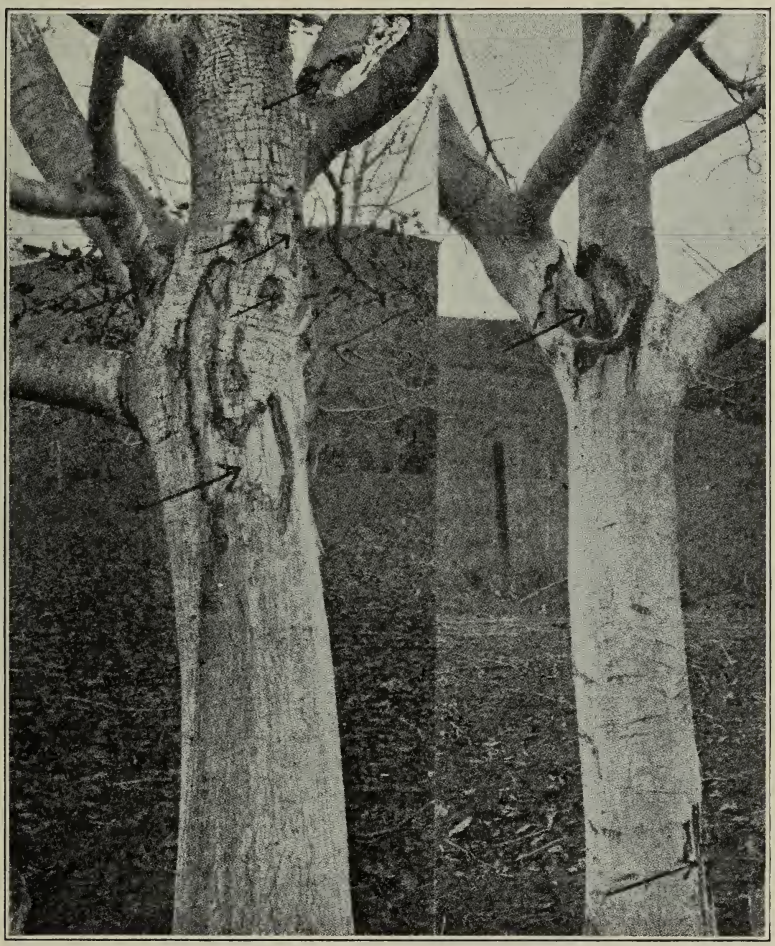


Fig. 37.—Walnut trees showing the location of Melaxuma cankers that had been cut out and treated with Bordeaux paste the year previous. Notice the rows of holes in the bark of one tree, made by sapsuckers. These probably served in this case as a partial means of infection. (From Bulletin 261.)

This same organism causes crown gall on walnut trees. The gall is a large overgrowth which usually occurs on the crown but may occur higher up on the tree. This overgrowth is rough and somewhat spongy and is not easily confused with the normal overgrowth which often

occurs at the bud union of the walnut tree. The galls will slowly grow in size until the trees may become girdled after several years.

It is advisable to cut out the galls while they are small and carefully disinfect the wounds. Then paint the wounds with a weather proof paint. Figure 38 shows a long-standing case of crown gall.

Crown Rot.—This disease has been under observation by the University of California Citrus Experiment Station since 1919.

Fig. 38.—A long-standing case of crown gall. (Photograph by C. O. Smith.)

The[21] first series of observations made on the disease in the field brought to light the apparent fact that the disease was usually associated with the southern California black walnut (*Juglans californica*) when used as a rootstock and that it usually occurred on trees located in poorly drained soil or where excessive moisture was present.

As the name indicates the disease involves the bark below the ground in the region of the crown, extending not infrequently a short distance outward onto the lateral roots. In well-advanced stages, the tap root, when present, is dead, due as often to a girdling effect at or below the crown as to the downward development of the disease. A splendid opportunity for the examination of many infested trees was offered during the process of pulling a grove which was abandoned in 1923 on account of the disease. Rarely were the lateral roots affected more than one or two feet from the crown, indicating that the disease is confined very largely to the crown region.

[21] From: Barrett, J. T., and C. O. Smith. Walnut tree crown rot. Diamond Walnut News 8(5):4. December, 1926.

The first indication of infection (so far as the general appearance of the tree is concerned) is a somewhat stunted appearance of the tree, sparse foliage, lack of twig growth, and a yellowish tint in the foliage. [This is illustrated by figure 39.] The yield may be exceptionally heavy. In more advanced cases the trees appear drought-stricken in midsummer, the leaves turn yellow and drop off, leaving a crop of nuts exposed to shrivel and drop off. Such a tree usually succumbs the following spring.

Fig. 39.—Young walnut tree killed by crown rot. It was probably subject to disease for several years before death. (Photograph by W. B. Hooper.)

Unfortunately trees showing the symptoms as described are found upon examination of the crown to have a well-advanced case of the disease (fig. 40). The second condition mentioned is associated with a completely girdled crown. There is reason for believing that a tree may be infected for a number of years before being killed.

The lesion on the crown is characterized by a soft, black, frequently spongy and decayed condition just below the bud union and under the ground. The margin of the diseased area usually stops at the line of the bud union. Occasionally, however, it extends over this line well up on the trunk. Certain evidence indicates this type of disease to be due to but one of two organisms capable of inducing crown rot.

In numerous attempts to isolate an organism from lesions in different stages of development on the black walnut stocks, repeated failure has been met with. A number of bacteria have been secured and tested out with negative results. Two fungi have been isolated, however, which have been shown to have a causal relation to the disease.

It is of particular interest to note that one of these is *Phytophthora* of the *Pythiacystis* type, resembling the organism responsible for brown rot of lemons and gummosis of citrus and certain deciduous fruit trees. The other fungus is closely related to *Pythiacystis* and appears to be *Phytophthora cactorum.* The latter fungus was in each case isolated from lesions on the English trunk.

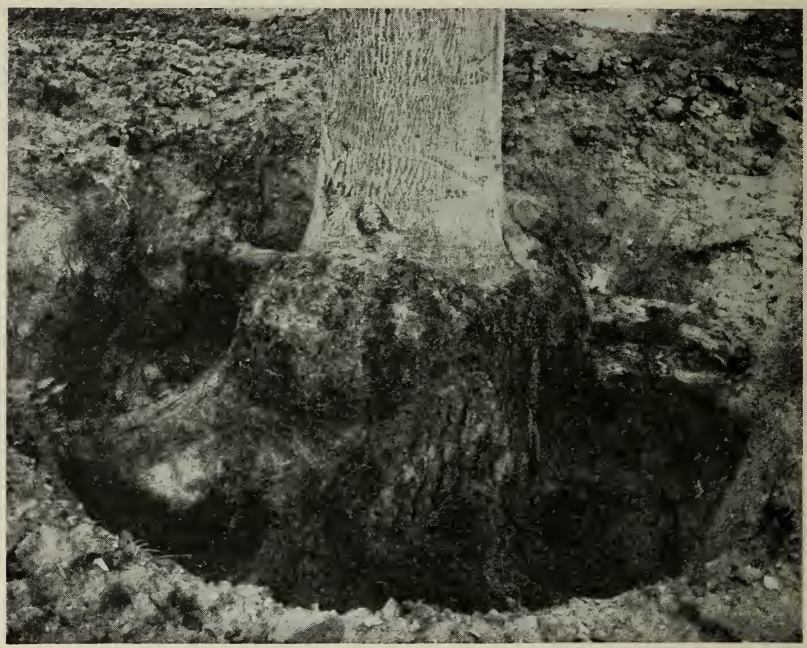


Fig. 40.—Crown rot well established on black-walnut root. (Photograph by W. B. Hooper.)

Both the *Pythiacystis* and *Phytophthora* cultures produce infection on northern and southern black walnut, and in some cases positive results have been secured on the English species.

Any provision to prevent water standing about the trees and to aid in keeping soil about the crown fairly dry is considered the first step in the prevention of infection.

In orchards on the black walnut root, particularly the southern black, and where cases of the disease are known to occur, the removal of the soil from the crown is suggested. This will allow careful inspection and treatment where necessary, and the exposure of the crown bark to the drying effect of the air will be beneficial.

It is essential, we believe, to remove by surgical methods all lesions of any size and depth that can be reached. Many of the incipient superficial spots will undoubtedly be killed by drying, but it is not safe to depend too greatly on this control method. All diseased tissue should be removed with suitable tools. The wound should be covered with a solution of cyanide of mercury, one part in five hundred of a 25 per cent solution of denatured alcohol. A small sponge securely tied to a stick makes a good swab for applying the solution.

Winter Injury or Die-Back.—This trouble of the walnut tree has been made the subject of considerable study by Smith[22] and Batchelor and Reed.[23] Perhaps it can be summarized best at this time by quoting from the last-mentioned authors.

Fig. 41.—The effect of winter drought, and recovery of the tree two years later, after irrigation. (From Bulletin 332.)

Winter injury or die-back of walnuts is characterized by a death of the tops of the trees. Such injury is usually first noticeable during the early spring.

The most common causes of the winter injury or die-back are given below.

1. Early autumn frosts kill the immature, growing shoots. Young walnut trees are more subject to injury from this cause than older trees, because they are usually later in maturing their new wood. Such frosts cause the foliage to drop prematurely and injure the growing tips of the twigs. The denuded twigs are subject to further injury from subsequent fall and winter sunburn. The

[22] Smith, R. E. Walnut culture in California. California Agr. Exp. Sta. Bul. 231:372. 1912. (Out of print.)

[23] Batchelor, L. D., and H. S. Reed. Winter injury or die-back of the walnut. California Agr. Exp. Sta. Cir. 216:1–20. 1919. (Out of print.)

presence or extent of this injury is usually overlooked until the following spring.

To reduce the danger from autumn frosts it is advisable to withhold the late summer irrigation in order to promote the early maturity of the trees.

2. Winter drought causes die-back in either young or bearing walnut groves. Trees suffering from this condition fail to make new growth in the spring, except from the trunks or main limbs. The new growth on such trees has lost so much water during the winter that the buds are unable to develop in spring. The cause of the die-back has been found to be due to an extremely low moisture content of the soil during a large part of the winter. Under such conditions, the water lost from the young shoots during the winter cannot be replenished by the root system, and the shoots die from desiccation.

Fall and winter irrigation of the walnut groves has been found to eliminate the injury from winter drought. The amount of irrigation water to be applied will depend upon the type of soil, the amount of soil moisture present at the end of the harvest season, and the rainfall which may be expected later in the season. [Figure 41 shows a walnut tree thus affected and afterward cured by winter irrigation.]

The late fall or early winter irrigation of the walnut groves, especially in the inland valleys, may be looked upon as an insurance policy against this form of die-back. To be effective, it should be applied in December or January. In some years subsequent rains will show that the die-back insurance policy was unnecessary. The same apparent objection, however, applies to fire insurance on the barn or house during the years that there are no fires on the property.

3. A high water table may be a contributing factor in die-back. A permanently high water table may cause young trees to prolong their growing season, with the result that they are killed by frosts. The sudden rise of a fluctuating water table may kill a large part of the root system and thus cause a reduction of the moisture conducted to the top of the tree. This in turn will produce a typical die-back in the tops of mature trees.

4. Alkali soils containing such a high salt content as to injure the roots systems of walnut trees also cause the tops of the trees to die back in response to the root injury. In the initial stages of alkali injury the leaves turn brown at the margin and fall prematurely. The denuded shoots sometimes put out a new set of leaves in the fall. The top of the tree gradually dies back until the entire tree is lost.

If the injury is being caused by irrigation water containing too much alkali, obviously the use of such water should be discontinued. Trees which have been severely injured by this cause have been known to recover to a marked degree after the use of suitable irrigation water for several years.

HARVESTING

During favorable seasons and in well-cared-for groves, the husks of the nuts crack open and adhere temporarily to the twigs, while the nuts drop clean-shelled to the ground. This natural dropping of the great bulk of the nuts occurs with most varieties between September 1 and November 7. There are usually enough nuts on the ground to

justify the first picking by the second week in September. The natural falling of the nuts is hastened during the harvesting process by shaking the trees with long poles having hooks attached to the ends.

During the harvest period the nuts are picked up at least three or four times before the total crop has matured and dropped. It is not considered good practice to allow the nuts to remain for a long time on the ground. Nuts thus neglected are subject to the work of ants in the kernels, and may be rained on by the autumn showers. The effect of rain upon the nuts may be entirely superficial if they are picked up promptly after they are dry again. At the best, however, they will be dirty and more or less stained, causing extra work of washing in preparing them for the packing-house, and making proper bleaching more difficult. Nuts long neglected on the ground after a rain become moldy and stained on the outside of the shells, especially those which have a portion of the husk adhering to them. If the stain of the mold is pronounced it will be impossible to bleach it, and the nut must be graded as a cull. If further neglected the mold from the outside of the nut and the inside of the attached husk may spread to the kernel through the base of the nut, and thus lower its value even as a cull nut.

A certain percentage of the nuts will drop with the husks adhering to them. These are commonly known as "stick-tights," and are likely to be inferior to the clean-shelled nuts in their plumpness and in the appearance of the kernels. There is usually a high percentage of blanks, shriveled, moldy, and dark-colored kernels among the stick-tight nuts. The percentage of stick-tights is greater during seasons of abnormally high temperatures, when the nuts are sunburned and also when the husks are affected with blight. Again, trees which suffer from drought during the latter part of the growing period, or which are subject to the attacks of the aphis, red spider, or for any other reason lose their leaves prematurely, produce a high percentage of stick-tights and inferior nuts.

A small percentage of nuts may mold after the husks crack and before the nuts drop from the trees. Stick-tight nuts are more likely to be moldy at the time they drop from the trees than those which drop from the trees free from their husks. The percentage of moldy nuts will increase if stick-tights are left on the ground for a week or ten days. Stick-tight nuts should be harvested with dispatch so they will not become so moldy as to be classed as culls.[24]

[24] For a detailed discussion of the effect of harvesting methods on the prevalence of moldy nuts see: Batchelor, L. D. Methods of harvesting and irrigation in relation to moldy walnuts. California Agr. Exp. Sta. Bul. 367:1–24. 1923.

The commercial grading of walnuts is much more carefully done at present than it was a decade ago. The grades are determined first by the percentage of edible kernels, and second by the percentage of light-colored kernels. The effect of harvesting methods upon the color of the kernels may be as pronounced as its effect upon the percentage of moldy nuts.

Experiments on the effect of the season of harvesting upon the commercial grade of the nuts have been conducted by the Citrus Experiment Station. The following summary describes these results.[25]

Early Harvesting.—The experiments herein described were carried on in the variety orchard of the Citrus Experiment Station at Riverside. Five varieties of walnuts were harvested early, at which time one tree of each variety was left untouched for the late harvesting to be described below. At the time of the early harvesting 50 per cent or more of the shucks were clearly starting to crack open and were still hanging on the tree. A few of the early nuts had dropped from the shucks and were under the trees on the ground. The trees were shaken at the first picking so fully 80 per cent of the crop was harvested at once, the plan being to knock all the crop off that could readily be shucked by hand. In doing so it was only natural that a small percentage of the nuts which were shaken off were actually too green to be separated easily from the shucks. The entire lot was passed through a power-driven shucking machine and the nuts were washed as they passed out of the machine. The nuts were then dried in trays in the ordinary way.

Late Harvesting.—The remaining trees of each of the five varieties were harvested three weeks later, when the majority of the crop had dropped naturally to the ground, at which time the trees were cleaned of the remainder of the crop. Most of the nuts were free from their shucks, and none of this portion of the crop passed through the shucking machine.

After both lots were cured, ordinary grab samples were taken from each variety for each of the two methods of harvesting. After discarding all nuts which were culls because of exterior appearances and substituting additional nuts for all "blanks," one hundred nuts were cracked for each respective class. The Association grading requirements were followed in classifying the results as set forth in table 12.

Comparison of Early and Late Harvesting.—It is clear from the data presented in table 12 that the season of harvest had a profound

[25] Batchelor, L. D. The early harvesting of walnuts. Diamond Walnut News 9(5):9. Dec., 1927.

effect on the percentage of light-colored kernels and thus on the commercial value of the nuts. There was considerable variation in the response of the several varieties, the Woodland and the Ehrhardt just barely making the Diamond grade even though harvested early. All the early harvesting was done on the same date, at which time the Ehrhardt in particular was notably more mature than the other varieties. For this particular variety the early harvest could easily have been a week earlier.

TABLE 12

Effect of Season of Harvest on Color of Walnut Kernels and Commercial Grade of Nuts

Vareity	Season of harvest	Light-colored kernels, per cent	Sound, per cent	Commercial grade
Payne	Early	81	99	Diamond
	Late	41	97	Emerald
Woodland	Early	69	97	Diamond
	Late	34	95	Offgrade
Ehrhardt	Early	65	97	Diamond
	Late	35	94	Offgrade
Wasson	Early	72	98	Diamond
	Late	46	92	Emerald
Blackmer	Early	90	100	Diamond
	Late	32	96	Offgrade
Average	Early	75	98	Diamond
	Late	38	95	Offgrade

The success of the application of the early-harvesting methods will depend upon the efforts of each individual farmer in earnestly carrying out the program to give it a fair trial under his own conditions. It may be also expected to vary according to different varieties. The Payne and Neff varieties have both proved well adapted to this method of harvesting. The varying climatic conditions of the different walnut-growing districts may have a bearing on the subject and may also cause varying measures of success. The most marked effects of harvesting upon the color of the walnut kernels have been noted in Riverside, Orange, and San Joaquin counties. In any event this may well be the subject of careful observation trial by walnut growers in the various districts of the state. The difference in the value of Diamond and Offgrade walnuts will amply repay for much careful effort on the part of progressive walnut growers to improve the quality of their crop.

HULLING

If the harvest operations are hastened in an attempt to produce high-quality nuts, the frequent shaking of the trees will probably cause a portion of the nuts to fall with the hulls still attached. If discretion is used in supervising the shaking of the trees, the large majority of these nuts should be in such condition that they can be readily hulled. Most nuts the hulls of which have cracked can readily be hulled by hand without any of the hull being left attached to the shell. Some varieties, such as the Payne, Mayette, and Blackmer, are especially easily hulled, and even those specimens which do not show any readily visible cracks in the hull can nevertheless be hulled completely by hand or by machinery.

These nuts may either be hulled as they are picked up in the orchard, or the entire picking may be hauled to one central location regardless of condition and all hulled by machine. The latter practice is the quickest and most economical of the two with respect to harvesting costs. The pickers gather up all the nuts and make no attempt to cull or clean them in the field. This method of picking up the nuts with the hulls adhering as they fell from the tree is best used when the crop can be run through a mechanical huller as soon as it is brought in from the orchard.

The most practical use of the hulling machine occurs when all the nuts are passed through the machine as they come from the field and no attempt is made to separate the clean nuts from those with the hulls attached.

The use of a hulling machine enables the grower to push the harvest much more rapidly than otherwise could be done. This is due to the fact that the mechanical huller will reduce hulling costs, which would be high if a large percentage of the nuts had to be hulled by means of hand labor.

It should be borne in mind, however, that a mechanical huller *will not hull* nuts which *cannot be hulled by hand labor.* It is a labor-saving device only and should be used as such in the general program of speeding up the harvest, which in turn means a higher quality crop.

WASHING

The nuts must be washed immediately after they come through the huller. This is to remove the juice of the crushed hulls which would otherwise stain the shell and make it hard to bleach. If most of the nuts are dirty from lying on the ground during showers it is neces-

sary to wash them. They are thus cleansed of all loose foreign material. The washing process will not remove the stain on the shells due to sunburned and blighted husks sticking to the nuts.

Washing is done in a large cylindrical drum made of a coarse wire netting in which the nuts are slowly revolved under a stream of water. If nuts are to be washed by this process they should pass through the drum in a continuous stream so that any individual nut will not be in the drum more than 2 or 3 minutes. The prolonged rotation of a lot of nuts in such a device cracks them, loosens and bruises the kernels, and will soon make culls of the whole lot. There is no need for washing the clean nuts.

DEHYDRATION[26]

After walnuts are hulled they must be promptly and thoroughly dried before delivery to the packing-house in order that evaporation of the excess moisture contained in both kernel and shell will:

1. Give a product of stable weight.
2. Prevent molding or darkening of kernels.
3. Permit efficient bleaching.

The amount of moisture which must be evaporated varies greatly, but decreases as the harvest season progresses. Uncured nuts may contain anywhere from 15 to over 40 per cent moisture, averaging 25 per cent. Adequately dried nuts average 6 per cent, and should not exceed 8 per cent in moisture. An average of about 18 per cent of the green weight of the nuts is evaporated during drying.

Until recent years this drying was accomplished by the natural means of drying in the sun, that is, by exposing the nuts in shallow, slat-bottom trays supported on saw-horses in a drying-yard. Although easy of operation and employing only simple equipment, this method was always subject to uncontrollable weather hazards, which frequently delayed drying and marketing or injured the walnuts. Although a few growers had previously constructed and used artificially heated dryers for their walnuts, the extensive use of dehydraters has come about during the past ten years. The investigations of Batchelor and Christie, and the activities of several manufacturers of dehydraters, caused such wide interest among walnut growers that there were 363 walnut dehydraters in operation in 1928 and it is estimated that at least half of the state crop was dehydrated.

[26] This section supersedes: Batchelor, L. D., A. W. Christie, *et. al.* Sun-drying and dehydration of walnuts. California Agr. Exp. Sta. Bul. **376**:1–26. 1924. (Out of print.)

Advantages of Dehydration.—The rapid increase in the use of dehydraters has been caused by their advantages over natural drying, chief among which are:

1. Drying efficiency. Dehydraters operate independently of weather conditions, and accomplish a thorough and uniform drying of walnuts in an average of 24 hours. Rapid, constant dehydration arrests further molding or darkening of kernels, minimizes the splitting of shells so common in sun-drying, and if properly controlled eliminates inconvenience or loss from over-drying or under-drying.

2. Labor efficiency. The labor requirements for dehydration have been found to be much less than in sun-drying, one man being able to handle several tons a day, including the loading of the dehydrater and sacking of dried nuts. Automatic controls permit dehydraters to run without constant attention.

3. Marketing and packing-house efficiency. Since the peak of demand for walnuts comes in the fall before the normal peak of supply, any operation which speeds delivery of walnuts to eastern markets is valuable, not only in finding a ready market at the best prices, but also in preceding the later influx of imported walnuts. If during the peak of demand in the fall, California walnuts are not available in a given market, dealers are obliged to substitute foreign walnuts, and the loss of such sales cannot be regained. The increasing use of dehydraters has not only resulted in greater packing-house efficiency because of the steady supply of dried nuts, but the several days saved over sun-drying has resulted in earlier satisfaction of market demands.

4. Theft protection. Walnuts drying out of doors in trays have always tempted petty thieves, but walnuts being dried in dehydrater bins, locked if desired, are safe from such thievery.

Principles of Dehydrations.—The evaporation of moisture, or the change of water from the liquid to the vapor form, requires the absorption of a definite amount of *heat*. In dehydration this heat is brought to the walnuts by a continuous stream of air previously heated by contact with a furnace.

Oil is the most common fuel used in dehydration because it is the cheapest source of heat. Where natural gas is available at low rates its use is equally satisfactory. About 10 per cent of the walnut dehydraters in use are electrically heated. Even at as low a rate as 1 cent per kilowatt hour, electric heat has been found to be three to four times as expensive as oil at 6 cents per gallon, despite the much greater thermal efficiency of electrically-heated dehydraters. Conse-

quently the use of electricity has been confined to those growers who are willing to pay the higher cost because of certain features, such as simplicity in starting and controlling and reduced fire hazard. Even so, its use is restricted to places where a large electric load is already installed for pumping and can be diverted to a dehydrater at a low rate.

Walnuts have a critical temperature of 110° F, they must not be heated above this or the oil in the kernels will eventually become rancid and make them inedible. Unfortunately, this rancidity is not apparent immediately after over-heating but requires from a few weeks to several months to develop. Instances are on record where a lot of over-heated nuts was blended with other lots of normal nuts in a packing-house, and the development of rancidity in the over-heated nuts before they were consumed caused the entire lot to be rejected as a total loss.

Because of the spoilage caused by over-heating *all dehydraters used for walnuts must be equipped with an accurate and dependable thermostat* which will automatically prevent the temperature exceeding 110° F. The use of lower temperatures is not objectionable except that the lower the temperature the longer the time required for drying.

Humidity, or water vapor, normally present in air also affects the rate of drying. Increasing the temperature of the air decreases its relative humidity and correspondingly increases its moisture-absorbing capacity. For example, if air at 56° F and 100 per cent relative humidity (such as on a cool, rainy day) be heated to 110° F, the relative humidity falls to 25 per cent of saturation and the same air can absorb four times as much water as it held at 56° F. This explains why a dehydrater continues drying when natural drying is impossible or very slow.

Many dehydraters recirculate much of the warm exhaust air which has passed over the walnuts. While recirculation is not essential and many dehydraters give satisfactory results without it, recirculation tends to reduce fuel consumption and by affording more exact control of air conditions permits the operator to better control uniformity in moisture content of the dried nuts.

However, since the drying time increases rapidly by increase in the air humidity, care must be taken to restrict recirculation to an amount which will keep the relative humidity at 110° F below 25 per cent, preferably not over 20 per cent. Relative humidity is readily determinted by the comparative readings of a set of wet and dry bulb thermometers and reference to the chart accompanying such sets.

Air currents serve two essential purposes in a dehydrater. The air conveys heat to the nuts and passing on absorbs and removes the water vapor evaporated by that heat. Natural air currents are neither adequate nor controllable and consequently powerful fans of the centrifugal, multi-blade type are used to blow a large volume of air through the spaces between the walnuts as they lie in the bin.

Efficient dehydraters are provided with an air flow of 2,000 to 3,000 cubic feet of air per minute for each ton of walnuts. This air flow requires the expenditure of 1 to 1½ horsepower, preferably supplied by an electric motor.

As the air passes through a bin of walnuts, its drying power rapidly decreases because absorption of moisture causes a decrease in temperature and an increase in humidity. Even with vigorous air flow it has been found inadvisable to use a depth of walnuts greater than two feet. Otherwise the nuts on the intake side will reach dryness when the nuts on the exhaust side are still insufficiently dried.

By periodically reversing the direction of the air flow, the depth of nuts can be increased to about four feet. When this is done all nuts in the bin receive the same average air conditions and consequently dry at the uniform rates. Similar results are obtained by causing the nuts to mix in a slowly revolving cylinder through which the air passes from a central duct to the outside of the perforated cylinder walls.

Some types of drying equipment, not properly termed dehydraters, do not heat the air but merely use fans. This procedure protects the nuts from the weather and causes more rapid and constant drying than with natural sun drying but does not afford the speed or control obtained with dehydraters employing heat.

The capacity of any dehydrater in terms of pounds is measured by multiplying the number of cubic feet capacity by 20 pounds, the weight of a cubic foot of dried walnuts. A safe basis for estimating seasonal capacity is to assume that one full load will be dried every 24 hours under constant operation.

Selecting a Dehydrator.—Since the advent of the reliable manufacturer of dehydraters very few growers have found it economical to build their own. Unless a grower is well posted on the principles of heating and ventilating engineering, on which all successful dehydraters are designed, there is a good chance that a home-made dehydrater will not function as expected and may be more expensive than a reasonably priced commercial dehydrater by the time it is made to operate satisfactorily.

Walnuts can be successfully dried on trays in standard types of air-blast dehydraters such as used for prunes, raisins, apples, etc., provided they are equipped with a thermostatically controlled heating system which does not permit the temperature to exceed 110° F.

Cost of Dehydration.—Accurate measurements made on 22 commercially built dehydraters during normal mid-season operation in 1924 and 1925, showed the following average costs of operation per dried ton:

Labor at 40 cents an hour (including loading, operating, and sacking dried nuts)	$0.88
Fuel at 6 cents a gallon for oil or 50 cents per 1,000 cubic feet for natural gas	1.06
Power at 2 cents a kilowatt hour (includes fan, burners, elevator and light)	.58
Total operating cost per dried ton	$2.52

Corresponding figures on three electrically-heated dehydraters gave:

Labor	$0.72
Heat	3.73
Power	.36
Total operating cost per dried ton	$4.81

An extensive survey of the costs of natural drying showed an average labor cost of $3.75 per dry ton, which is 50 per cent greater than the combined cost of labor, fuel, and power in a dehydrater.

However, this advantage is more than offset by the lower fixed charges on the less expensive equipment used in sun-drying. Fixed charges (interest, depreciation, taxes, and insurance) vary greatly, not only with the nature of the equipment, but more particularly with the number of tons dried per year. The lower the first cost and the greater the tonnage handled the less will be the fixed charges per ton. The average fixed charge on sun-drying equipment was found to be $2.50 a ton, and on dehydraters $6.70 a ton. Adding these figures to the respective operating costs given above, the total for sun-drying was found to be $6.25, and for dehydration, $9.22. This is in line with the average charge of $10.00 a dry ton for custom dehydration, which many operators have found profitable in helping to pay the fixed charges on a dehydrater installed primarily for their own crop. Although official figures for later years are not available, it is known that lower first costs and increased operating efficiency are now resulting in lower costs per ton than obtained in former years.

Although the total cost of operating and maintenance of a dehydrater is about $\frac{1}{10}$ of a cent a pound more than the corresponding cost of sun-drying, the majority of growers feel that the several advantages of this modern method of drying are sufficient to counterbalance its slightly greater cost.

SUN-DRYING

Curing by means of sun-drying is accomplished by spreading the nuts out in shallow trays with bottoms made of slats spaced about one-half an inch apart. The nuts should not be left exposed to the sun during the entire day if the weather is especially clear and hot, for the drying will be so rapid that many of the nuts will crack open. If the trays are spread out in the morning and the nuts thoroughly stirred several times, the trays may be piled up when the nuts are warm. The slow drying which goes on while the trays are in piles of course prolongs the process, but prevents the splitting of poorly sealed nuts. Figure 42 shows a yard full of trays ready to be piled up after being thorough warmed by the morning sun. The trays should be so piled as to allow ventilation between them. At night the nuts should be protected against exposure to fog or dew. The alternate loss and gain in moisture when the nuts are exposed to fog at night and sunshine in the day may be the cause of splitting. Well-cured nuts should not show more than 2 or 3 per cent split; if they are exposed to the fog over 40 per cent may split.

PACKING

Although the packing and selling of the walnut crop in California is distinct from its production, it is nevertheless desirable for each grower to know how his nuts are to be graded and packed, in order that he may realize more fully the importance of delivering high-grade nuts to the packing-house. About 85 per cent of the walnut crop of California is packed and sold through the local houses which are affiliated with the California Walnut Growers Association. It may therefore be useful to relate briefly the processes followed in these houses in preparing the crop for shipment.

Eliminating Imperfect Nuts.—After being properly cured, the nuts are delivered to the local packing-house by the grower. They are first run over a rough screen which frees them from dirt and all foreign matter. From this screen the nuts pass through a suction machine, a device which lifts the blank or imperfectly filled nuts over

a trap and allows the full-meated nuts to pass through. From the suction machine the full-meated nuts pass on to an endless belt where they are culled to remove those stained, cracked and ill-shaped.

Bleaching.—The next treatment is that of bleaching. The nuts are given a bath of about three minutes' duration by passing them through large drums partially filled with a liquid bleaching solution, for the purpose of removing dirt and stain and brightening the appearance of the shells.

From the bleaching drums they are elevated and graded for size.

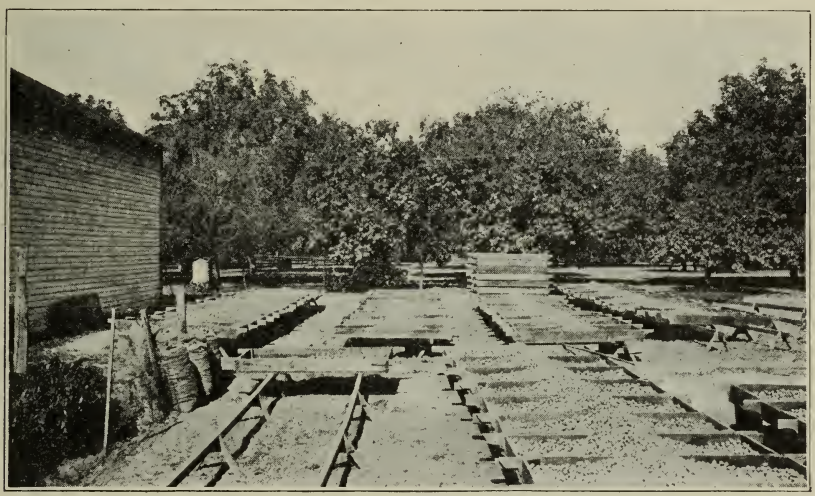


Fig. 42.—Drying walnuts by means of spreading them on trays placed on low racks. (From Bulletin 332.)

Grading.—For this process large cylindrical galvanized-iron graders are used. Each grader is 18 feet long and 40 inches in diameter, set on a 6-inch pitch and has a capacity to properly grade one and one-half tons of walnuts an hour.

The seedling walnuts are graded into two sizes. These grades are No. 1s, which pass over the openings in the grader, and Babies, which drop through the openings. The budded nuts are graded into three sizes. They are Large Budded, Medium Buds, and Babies.

A commercially graded pound of large nuts will comprise about 42 to 45 nuts, while the Baby grade requires nearly 80 nuts to make a pound. With the latter grade requiring nearly twice as many nuts to make a pound, often selling at 20 to 25 per cent less, it is clear that a grower should use every cultural and irrigation precaution to prevent the production of small nuts.

From the grader the walnuts again pass to a grading belt, where those that have not been bleached properly, or have been broken by the bleaching and grading operations, are removed. The perfect nuts then go into the drying-bins, and after a period of from 24 to 48 hours are packed, 100 pounds net weight, in burlap bags, ready for shipment.

SELLING THE CROP

As already noted, about 85 per cent of the walnut crop is sold by the California Walnut Growers Association. This central organization is a non-capital, non-profit, cooperative association, composed of a number of local packing associations. The board of directors is composed of a member from each local packing association. The local associations are also organized on cooperative principles. The local plants grade and pack the nuts of their members in accordance with the standard agreed upon by the board of directors of the central association. The central association, by a rigid inspection, maintains the standards set and performs its prime function of selling the crop. The walnut growers affiliated in this way receive the actual selling price of their nuts minus the bare cost of grading, packing and selling.

The walnut growers who do not belong to the cooperative associations usually sell their crops to the various independent packing firms, who later grade and pack the nuts according to their own standards.

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